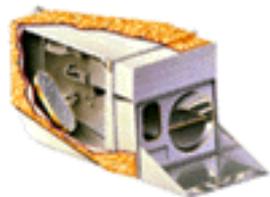
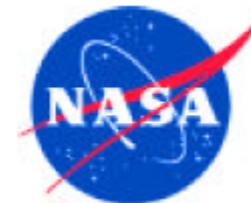




MODIS Instrument Operations Status



MCST Workshop at MST Meeting (October 18, 2018)

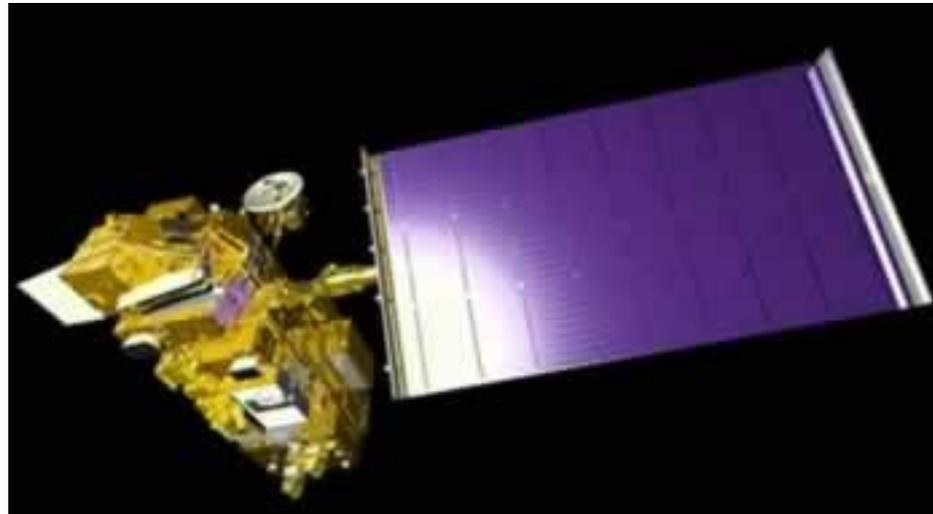




Terra Flight Operations



- Terra Spacecraft Status
 - 18+ years of successful operation
 - Safe Mode Occurred 02/18/16 – 02/24/16
 - Solid State Recorder – 32 supersets allocated: 0 lost since last STM
 - Battery – Anomaly on 10/13/09 resulted in loss of 1 cell (out of 54 total). No impact on operations or power availability.
 - Orbit Maneuvers: Drag Make-up #97-107, Inclination Adjustment #46-51





Aqua Flight Operations



- Aqua Spacecraft Status
 - 16+ years of successful operations
 - No major flight operation anomaly or extensive data losses since last STM
 - Solid State Recorder – Full data allocation
 - Battery – Fully functional
 - Orbit Maneuvers: Drag Make-up #107-130, Inclination Adjustment #52-61





MODIS Instrument Operations (Aqua)



- **Aqua MODIS is healthy and operating nominally**
- **Operational Configuration (No change since last STM)**
 - Same B-side configuration since launch
 - BB temperatures set at 285K
 - Cold FPA (SMIR and LWIR) controlled at 83K
- **Events**
 - SRCA Lamp Failure
 - Lunar Roll duration change
- **Concerns**
 - Loss of radiative cooler margin – Cold FPA not maintained at 83 K through entire orbit.
 - Has been improving over past few years



Aqua SRCA Lamp Failure



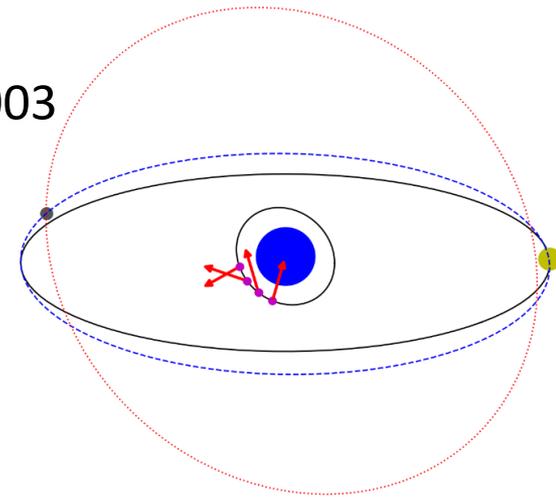
- 10W Lamp #4 failed on June 30th, 2016
 - During SRCA Spectral Calibration Part 2
 - Confirmed by running separate 10W calibrations with remaining functional lamps
- Now only one remaining 10W Lamp functional
 - Lamp #1
- SRCA Calibrations changed on Aqua to only use 1 lamp
 - SCS for Radiometric and Spatial Calibrations changed
 - Macro 31 load updated for Spectral
- No major impact to instrument calibration
- SRCA calibration frequencies have been reduced to preserve lamp life



Terra Lunar Deep Space Calibration – August 5, 2017



- Terra performed an accelerated pitch during spacecraft night so that instruments can view the moon and deep space
- Previous maneuvers were performed on March 26, 2003 (no lunar view) and April 14, 2003 (with lunar view)
 - No such maneuvers have been performed on Aqua
- MODIS was set to Day rate data collection during the event
- Moon was visible through Earth-View port
- CFWA temperatures increased during calibration
 - Returned to nominal temperatures after maneuver completion



* Orbital Geometry of DSC



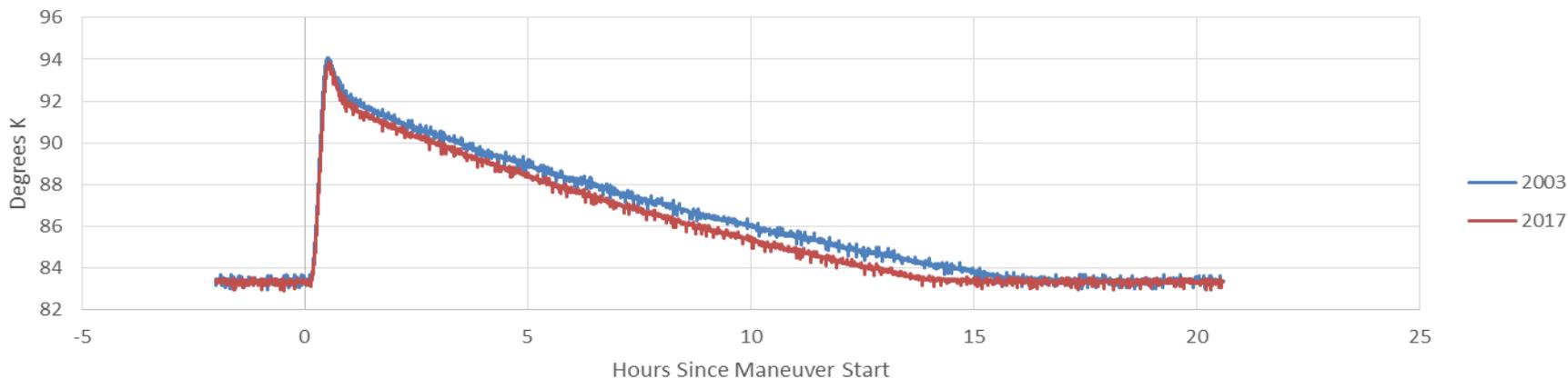
* Lunar Image from DSC



Terra Lunar Deep Space Calibration



SMIR Cold Focal Plane Temperature



LWIR Cold Focal Plane Temperature



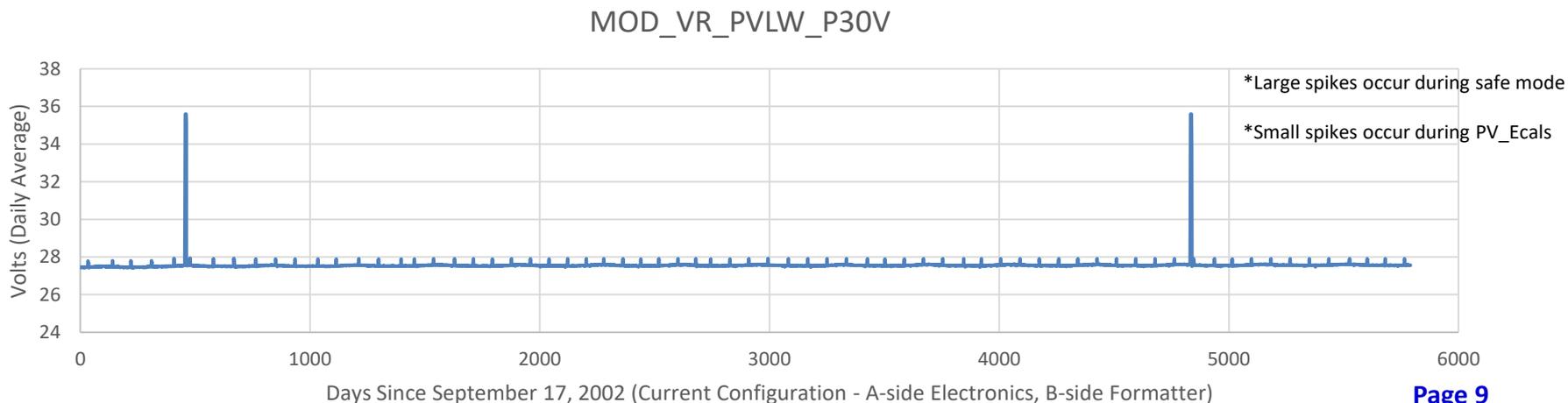
*2003 Data is from Lunar DSC



Terra Power Supply Alarms



- MOD_VR_PVLW_P30V flagged as RED on July 4, 2017
 - 30 volt power supply for PV LWIR Space-Viewing Analog Module Multiplexer
 - Lasted 60 seconds (1 telemetry update cycle)
 - Lower Limit is 26 V
 - Flagged at 25.7804 V
- Investigation found the alarm had flagged numerous times over the course of the mission
- After consultation with Joe Auchter, it was determined that this temporary low voltage did not pose a health threat to MODIS
- Flight Operations Alarm Threshold Lowered to 24 V

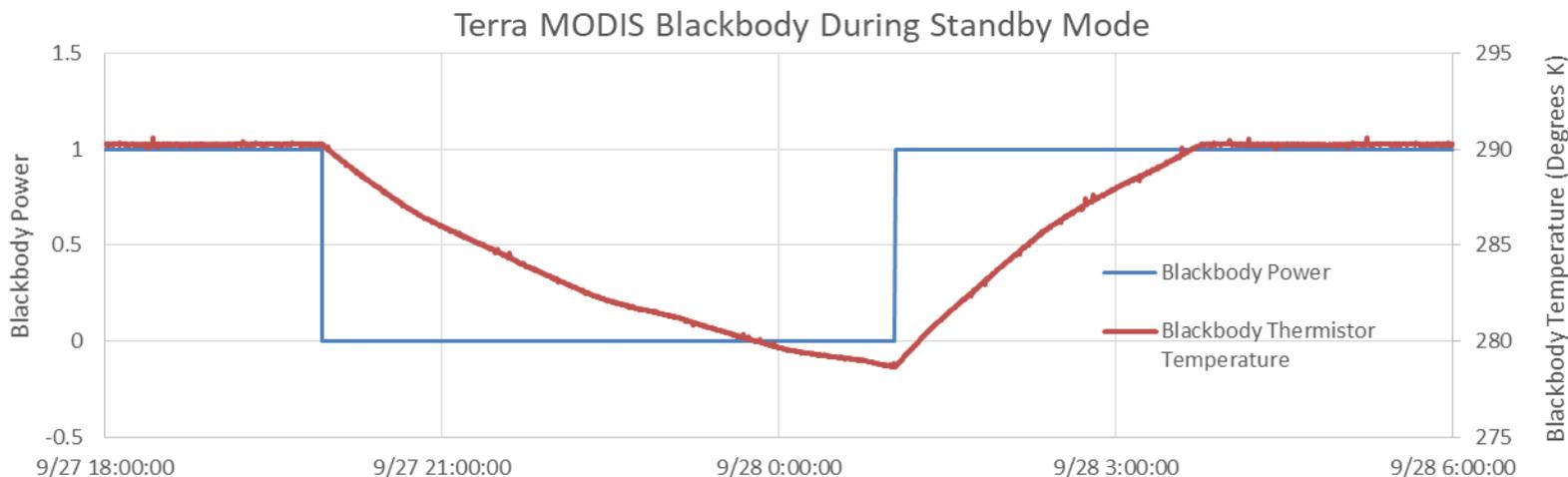




Terra Standby Mode – September 27, 2018



- Terra MODIS transitioned to Standby Mode on 2018/270 at 20:00 GMT
 - Caused by ATC (Automated Time Commands) not being loaded in time
 - Door positions and scan mirror activity remained unchanged
 - Blackbody was turned off
 - All MODIS related inhibit IDs were set
- MODIS returned to science mode on 2018/271 at 00:59 GMT
- The blackbody was powered on 2018/271 at 01:01 GMT
 - It was set to 290 K at 01:03 GMT
- All MODIS related inhibits were cleared by 2018/271 at 15:54 GMT
- There are no instrument health or safety concerns
- Science data remained in trend





DCR Background Information



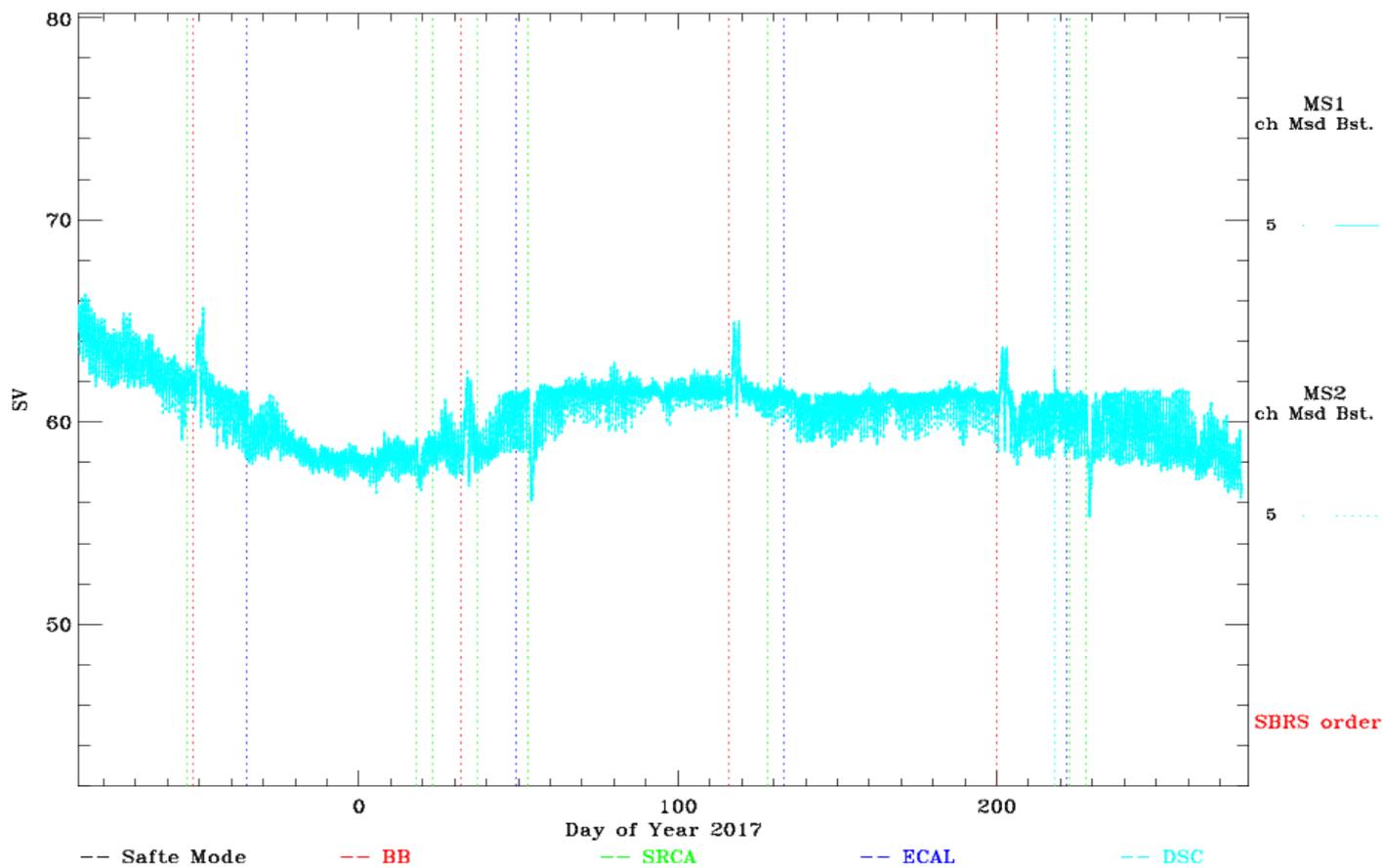
- The DC Restore adjusts the output from the detector analog-to-digital converter (ADC) to maintain the signal within a specified dynamic range
- The ADC Responsible for the Terra VIS FPA has shown a tendency to report odd multiples of 64 DN
 - Referred to as a “sticky bin”, the signal level favors the response at the raw digital number value (DN) of 64
 - At low signal levels, this can cause a noticeable discontinuity/level-of-error in data
- The ideal blackbody output table values are compared against the measured blackbody values on a scan-by-scan basis
 - If the difference is more than 150 DN, the DC restore is incremented



Terra Band 3 Sticking Behavior



Daily TERRA SV Trending – Band 3 Subframe 2 D 5





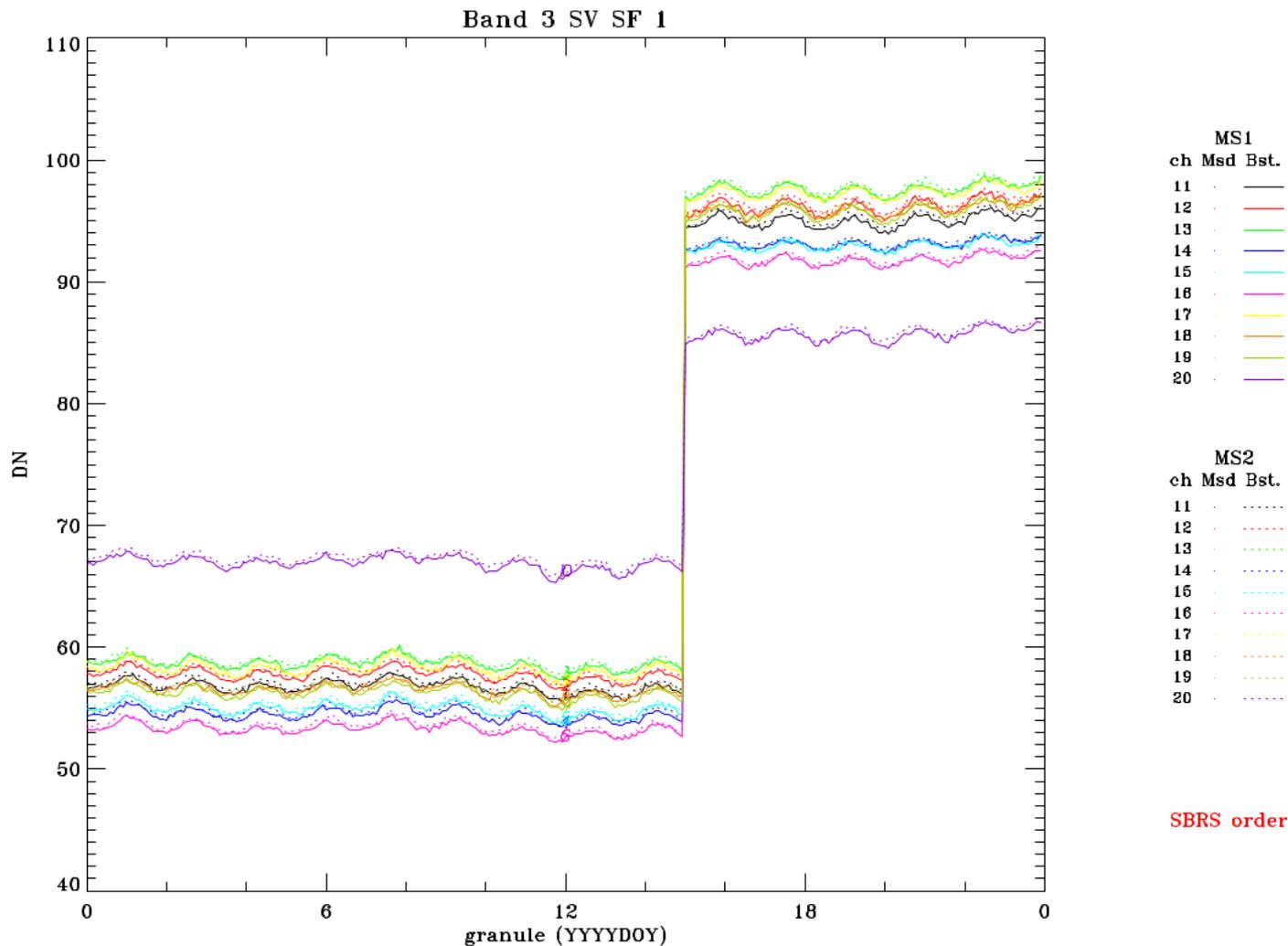
Terra Ideal Blackbody Output Table Changes



- The Ideal Blackbody Output Table consists of 1800 words
 - 36 Bands, 50 Temperature values for each band
- Values for bands 3, 4, 8, 10-12 were changed from 200 to 230
 - This changed the dynamic range for these bands from 50-350 to 80-380, thus getting us out of the “sticky bin” range
 - Band 9 has shown no “sticky bin” behavior
- Memory Load to change values for band 3 took place on December 13, 2017
- Memory Load to change values for bands 4, 8, 10-12 took place on April 10, 2018



Band 3 SV after Ideal Blackbody Output Table Change





Calibration Changes

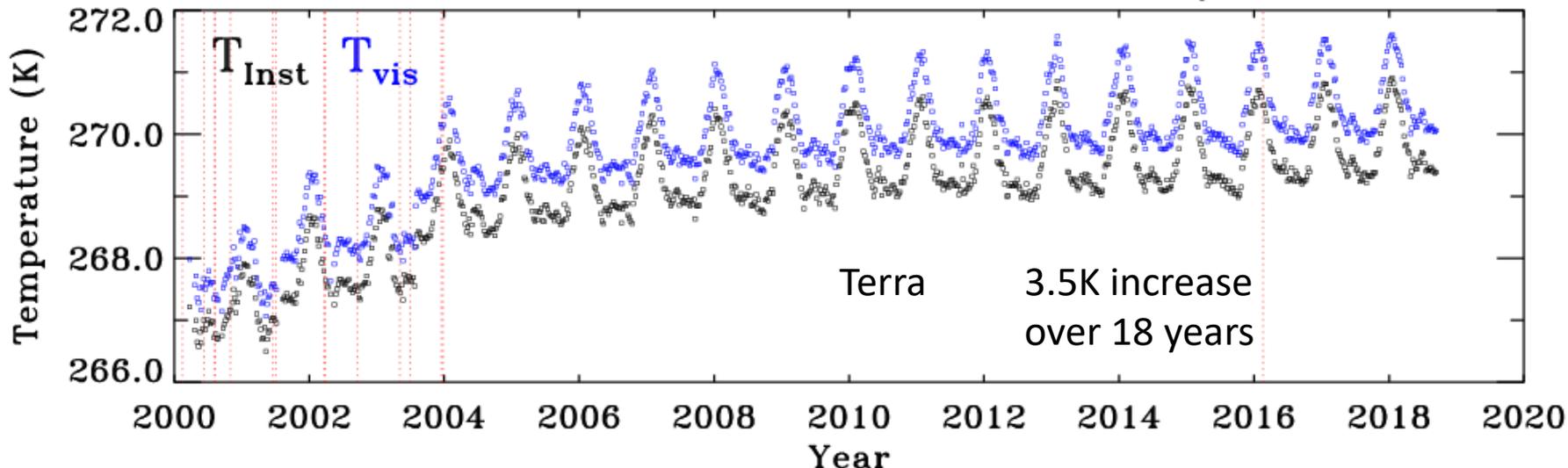


- Aqua Lunar Roll
 - Calibration time reduced from 6:46 to 3:46
 - Terra had the same time reduction in 2013
 - No impact on Radiometry
- PV_Ecal
 - Both instruments
 - Calibration will only be performed once annually
 - Previously performed quarterly
- SRCA Calibrations
 - Both instruments to conserve remaining lamp life
 - Full Radiometric
 - Quarterly, previously monthly
 - Spatial
 - Semi-annually, previously quarterly
 - Spectral
 - Semi-annually, previously tri-annually

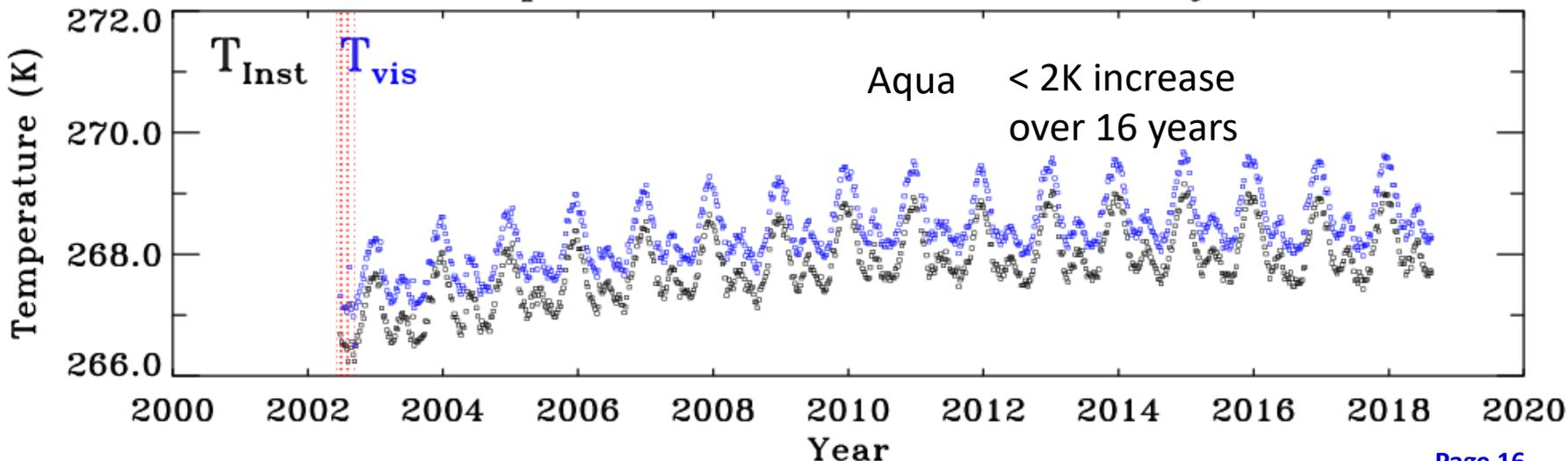


Instrument Temperature Trends

Terra Inst. & VIS FPA Telemetry



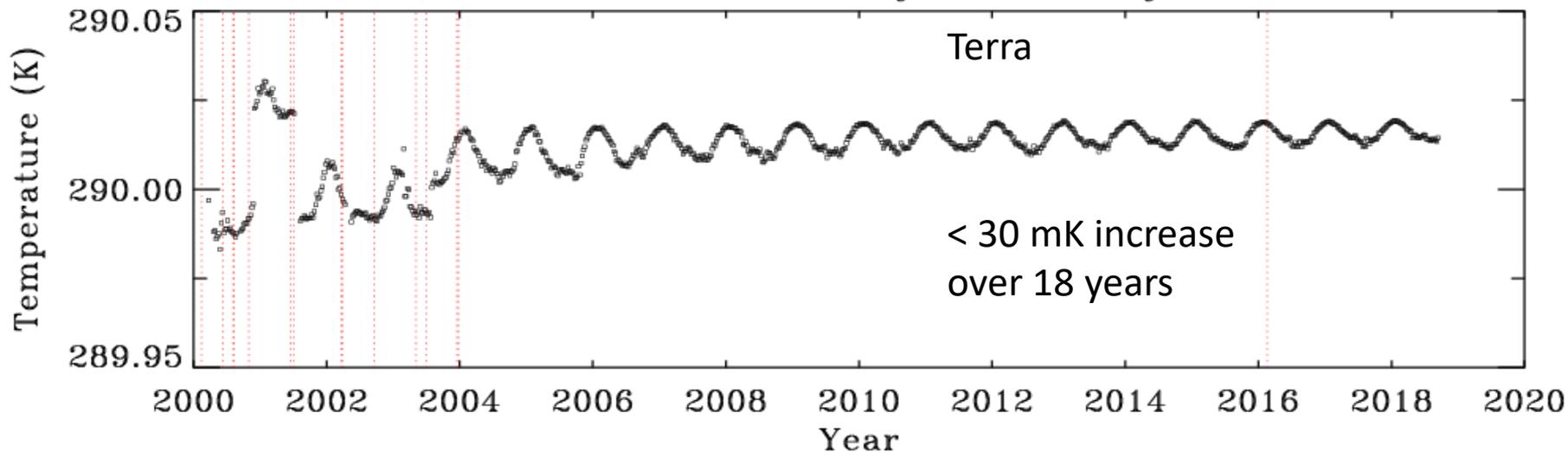
Aqua Inst. & VIS FPA Telemetry



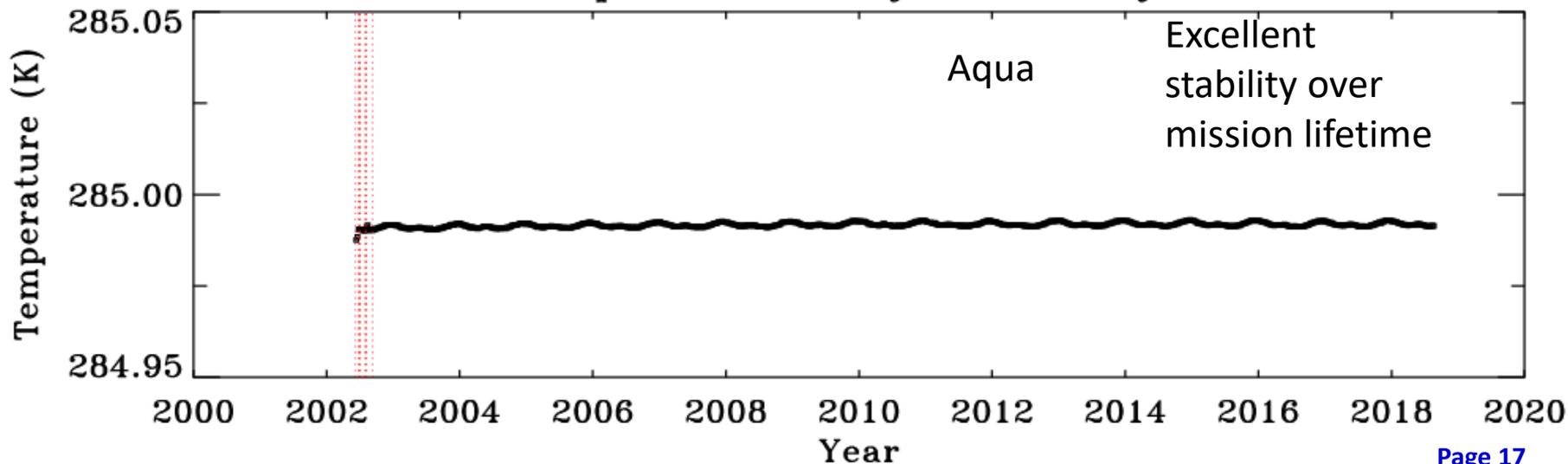


BB Temperature Trends

Terra Blackbody Telemetry



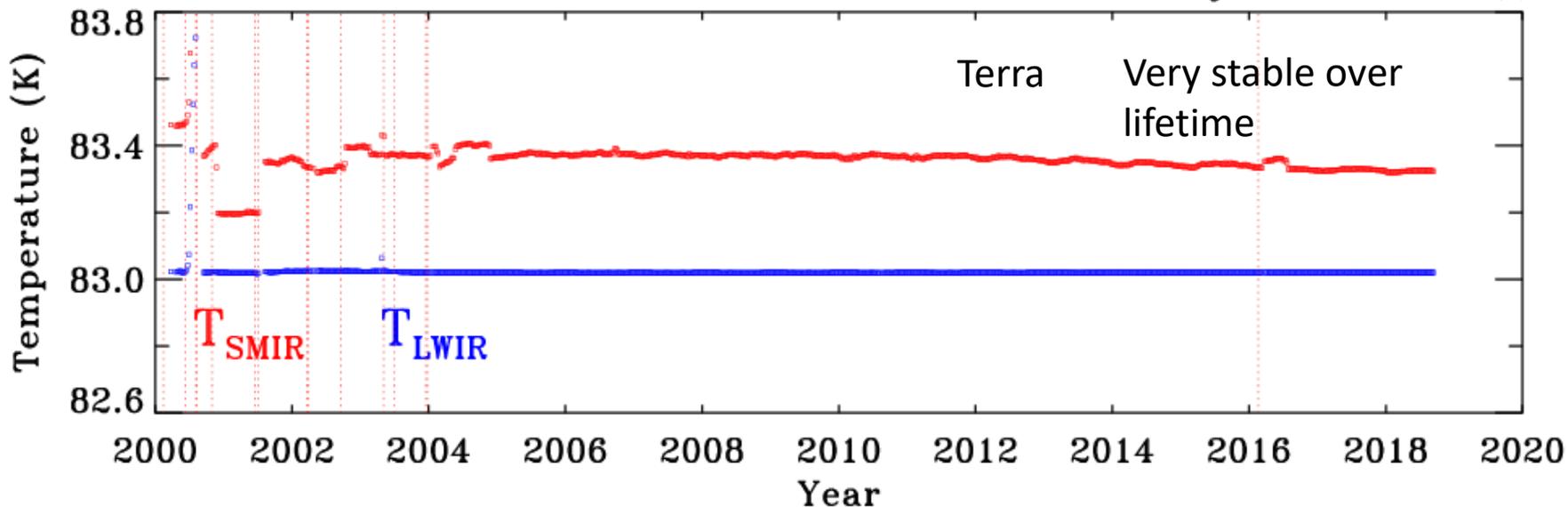
Aqua Blackbody Telemetry



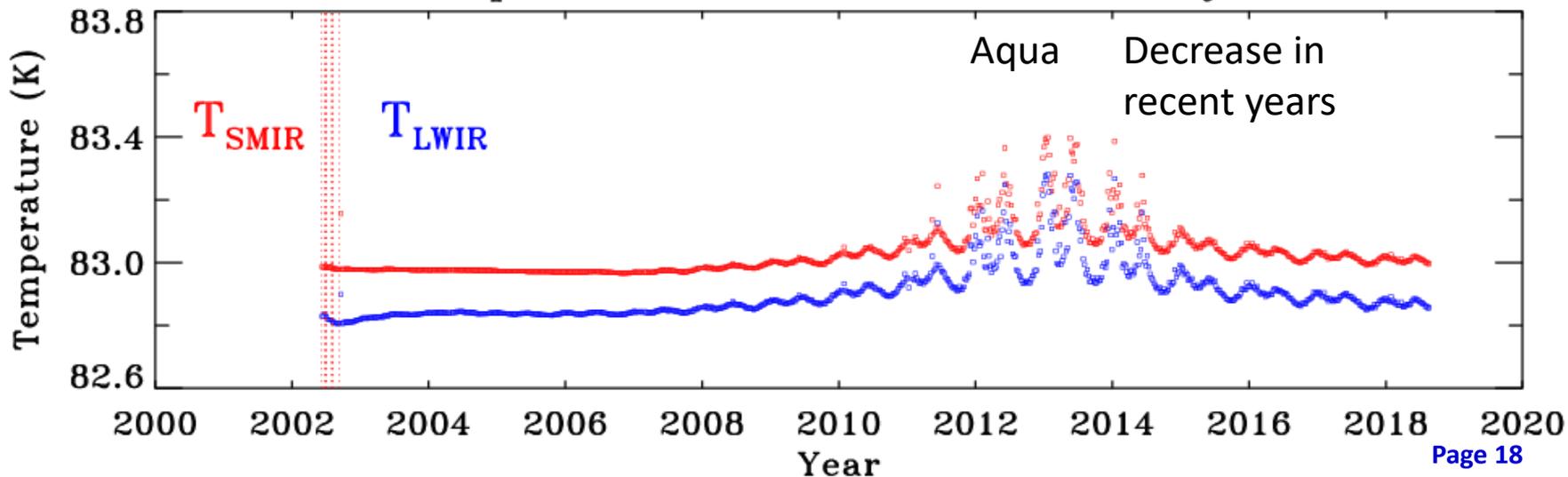


CFPA Temperature Trends

Terra SMIR & LWIR FPA Telemetry

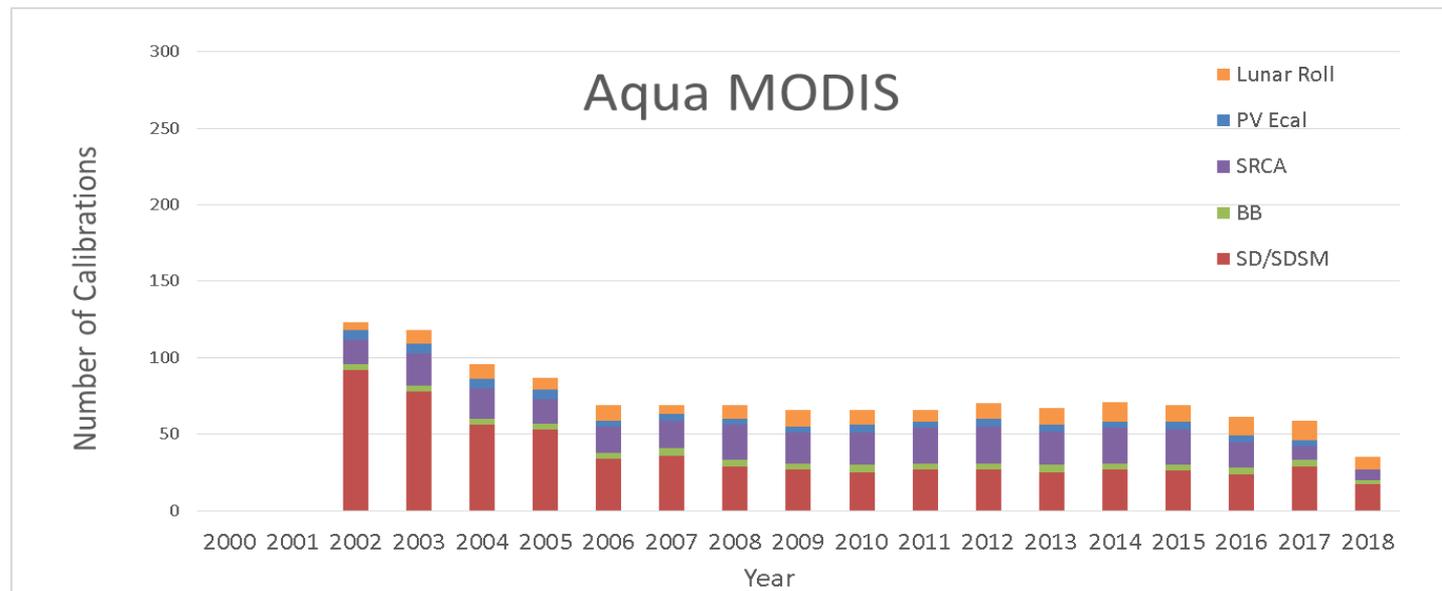
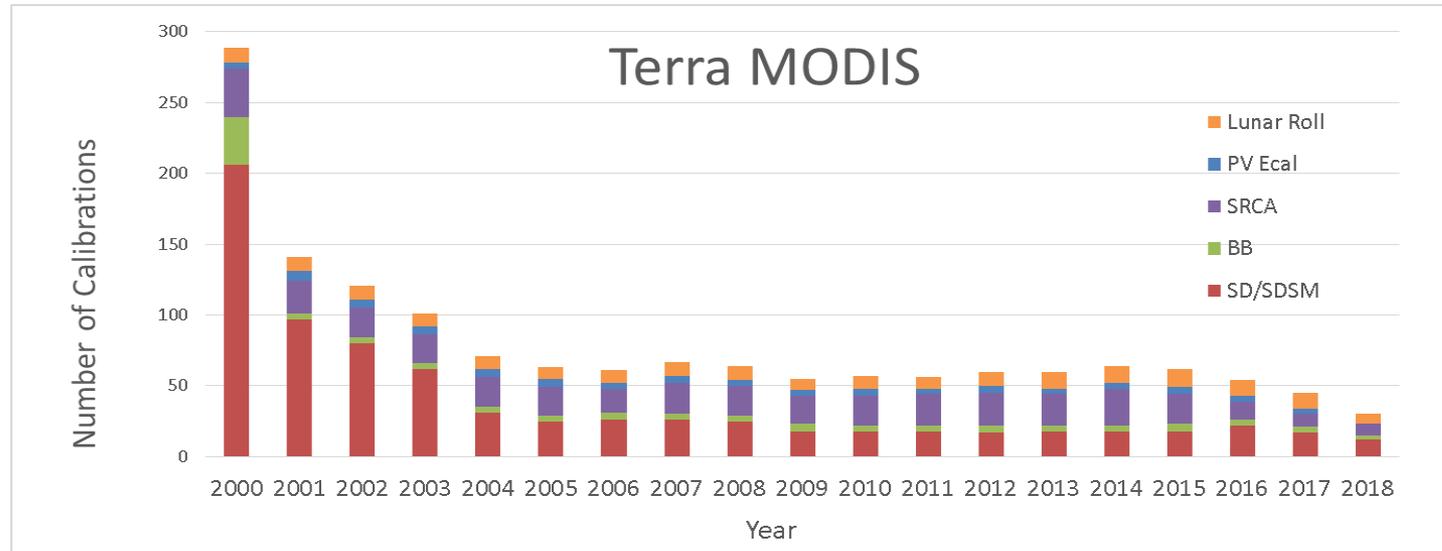


Aqua SMIR & LWIR FPA Telemetry





MODIS Calibration Operations





Terra/Aqua MODIS OBC Operations



T
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Activity	PL to 05/16	05/16 – present	Total
SD/SDSM#	714	42	756
BB WUCD	99	12	111
SRCA*	432	24	456
Electronic Cal	92	7	99
Lunar Roll	161	27	188

A
Q
U
A

Activity	PL to 05/16	05/16 - present	Total
SD/SDSM#	570	66	636
BB WUCD	61	9	70
SRCA*	314	26	340
Electronic Cal	71	6	77
Lunar Roll	135	30	165

Open & Screened Activities counted independently

* Includes Spatial, Spectral and Radiometric

05/16 = last Science Team Meeting



SRCA Calibrations



- Terra – 456 SRCA Calibrations
- Aqua – 340 SRCA Calibrations
- Please note there was a minor reconciliation of the usage numbers
- Lamps well within lifetime usage margins
- Aqua Lamp #4 Failure - 2016

Lamp Power		10W				1W	
Lamp #		1	2	3	4	1	2
Terra	Usage (hr)	375.4	172.1	190.3	138.7	589.8	310.8
	Life (hr)	500	500	500	500	4000	4000
	percent	75.1%	Failed on 11-20-2004	Failed on 2-18-2006	27.7%	14.7%	7.8%
Aqua	Usage (hr)	368.1	188.8	205.7	135.0	530.8	300.6
	Life (hr)	500	500	500	500	5000	5000
	percent	73.6%	Failed on 4-14-2003	Failed on 6-28-2005	Failed on 6-30-2016	10.6%	6.0%



Future Operational Considerations

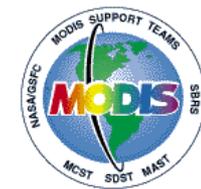


- Aqua MODIS CFWA temperature control
 - Currently set at 83K
 - Minimal impact on science data
 - Has begun trending in correct direction
- Aqua SD/SDSM door movements
 - Passed projected lifetime limit on movements
 - No change in current frequency of SD calibration activities planned at this time
- SRCA Lamps
 - Aqua currently has 1 working 10 W lamp
 - Frequency of all calibrations has been decreased

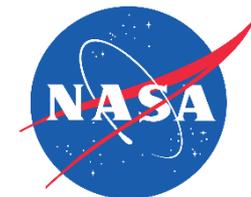
	PL to 05/16	05/16 to present	Total	Design Lifetime	% Used
Terra*	2146	0	2146	3022	71.01
Aqua+	3290	174	3464	3022	114.62

* As of 07/02/2003, SD Door in fixed 'open' position with screen in place

+ Aqua reached designed lifetime of door movement on DOY 2012/191 (July 2012).



MODIS Level 1B Code and LUT Status





MODIS L1B Major Changes



- **L1B major changes since last STM (6/06/2016)**
 - Phase out of Collection 5 (2005 - 2017)
 - Code versions: 7 (Terra); 6 (Aqua)
 - LUT versions: 195 (Terra); 142 (Aqua)
 - Release of Collection 6.1
 - Forward processing started since September 2017
 - Reprocessing completed in early 2018
- **Versions in Current Forward L1B Processing**
 - C6 (2012 – present): Terra V6.1.26; Aqua: V6.1.37
 - C6.1 (2017 – present): Terra V6.2.2; Aqua: V6.2.1
 - C6 & C6.1 LUT in the **Forward Update**:
 - RSB identical between C6 and C6.1 for Aqua and Terra
 - TEB & QA identical between C6 and C6.1 for Aqua only



C6.1 L1B Improvements



- EV_based gain and RVS calibration extended to mission long Aqua MODIS bands 1-4
- Terra MODIS LWIR crosstalk correction
Bands: 27 (6.72 μ m), 28 (7.33 μ m), 29 (8.55 μ m), 30 (9.73 μ m)

Detector Quality Flag after Safe Mode in 2016 (Terra)

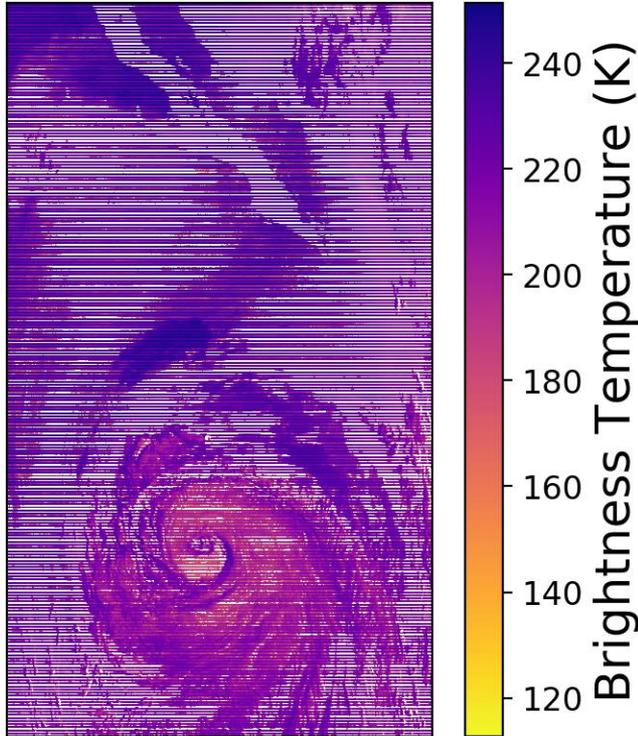
Terra MODIS Bands 27-30	Collection 6	Collection 6.1
Noisy Detectors	18	5
Inoperable Detectors	3	0



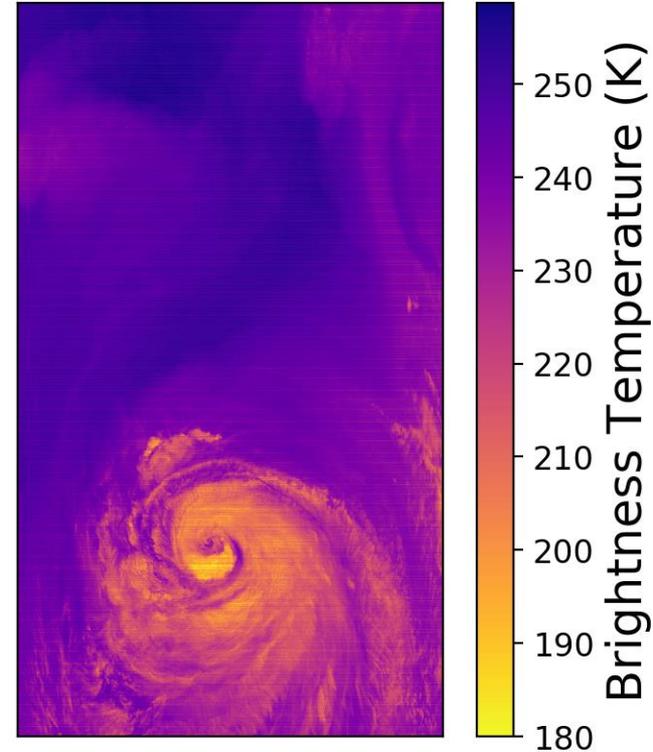
Terra C6.1 L1B Improvements



Collection 6



Collection 6.1



Terra Band 27, Baja California, July 3, 2018

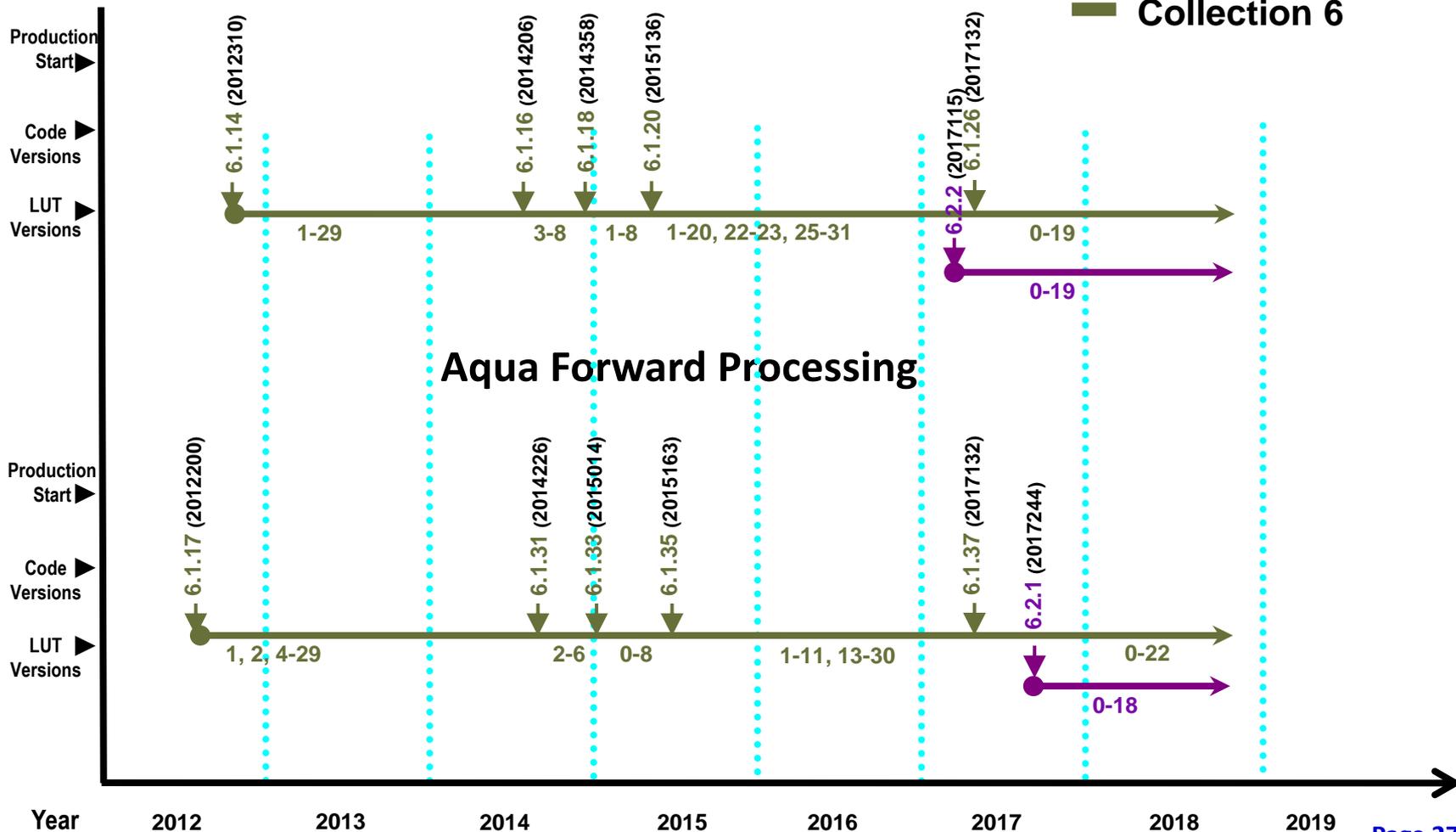


L1B Major Production Timeline



Terra Forward Processing

Collection 6.1
Collection 6





C5, C6 and C6.1 L1B LUT Updates



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Terra C5	10	14	14	17	19	18	18	21	15	17	17	12	3	
Terra C6								5	14	17	17	14	14	11
Terra C6.1													12	11
Aqua C5	6	9	11	9	9	13	15	13	11	14	14	15	3	
Aqua C6								7	11	15	15	16	13	13
Aqua C6.1													6	13
Total	16	23	25	26	28	31	33	46	51	63	63	57	51	48

- MCST also supports science teams by providing special L1B LUTs and/or test granules.



Summary



- C6.1 forward processing started September, 2017. The cross talk correction to Terra MODIS LWIR bands greatly improved the data quality of Terra MODIS L1B.
- Expected changes in the future collection:
 1. Cross-talk correction to MWIR, LWIR, and SWIR bands.
 2. LUT from improved calibration algorithm.
 3. Data format: HDF4 to NETCDF4/HDF5.



MODIS RSB Calibration and Performance





Highlights since the last STM (June, 2016)



- Terra MODIS
 - RSB continue to perform nominally after the safe-mode event (Feb, 2016)
 - Noticeable gain changes ($\sim 2\%$) for the SWIR bands observed after the safe-mode event. VIS/NIR bands show changes $< 1\%$
 - No new noisy/inoperable detectors since the last STM
 - Ideal BB update has mitigated the impacts due to “sticky bin” in the VIS bands
 - Improved algorithm to estimate the SD degradation at SWIR wavelengths (also implemented for Aqua MODIS)
 - C6.1 L1B reprocessed bands 1 and 2 LUT from 2012-2017.
- Aqua MODIS
 - No significant events since last STM. Instrument operating nominally with the OBC (SD, SDSM, SRCA) performing normally
 - No new noisy/inoperable detectors since the last STM
 - C6.1 L1B reprocess includes EV-based RVS extended to apply to bands 1-4. Mitigated the long-term reflectance drifts



RSB Calibration



- EV Reflectance

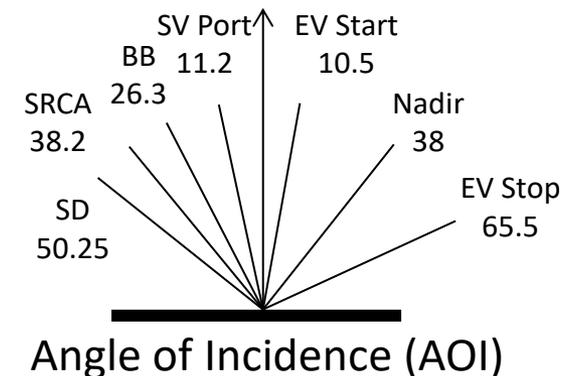
$$\rho_{EV} \cdot \cos(\theta_{EV}) = \frac{m_1 \cdot d_{Earth_Sun}^2 \cdot dn_{EV} \cdot (1 + k_{Inst} \cdot \Delta T_{Inst})}{RVS}$$

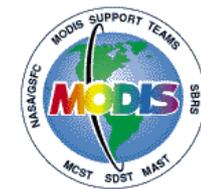
- Look-Up-Tables (LUTs) updated regularly for RSB

- m_1 : Inversely proportion to gain at the AOI of SD
- RVS : Sensor Response versus Scan angle (normalized to SD AOI)
- Uncertainty tables

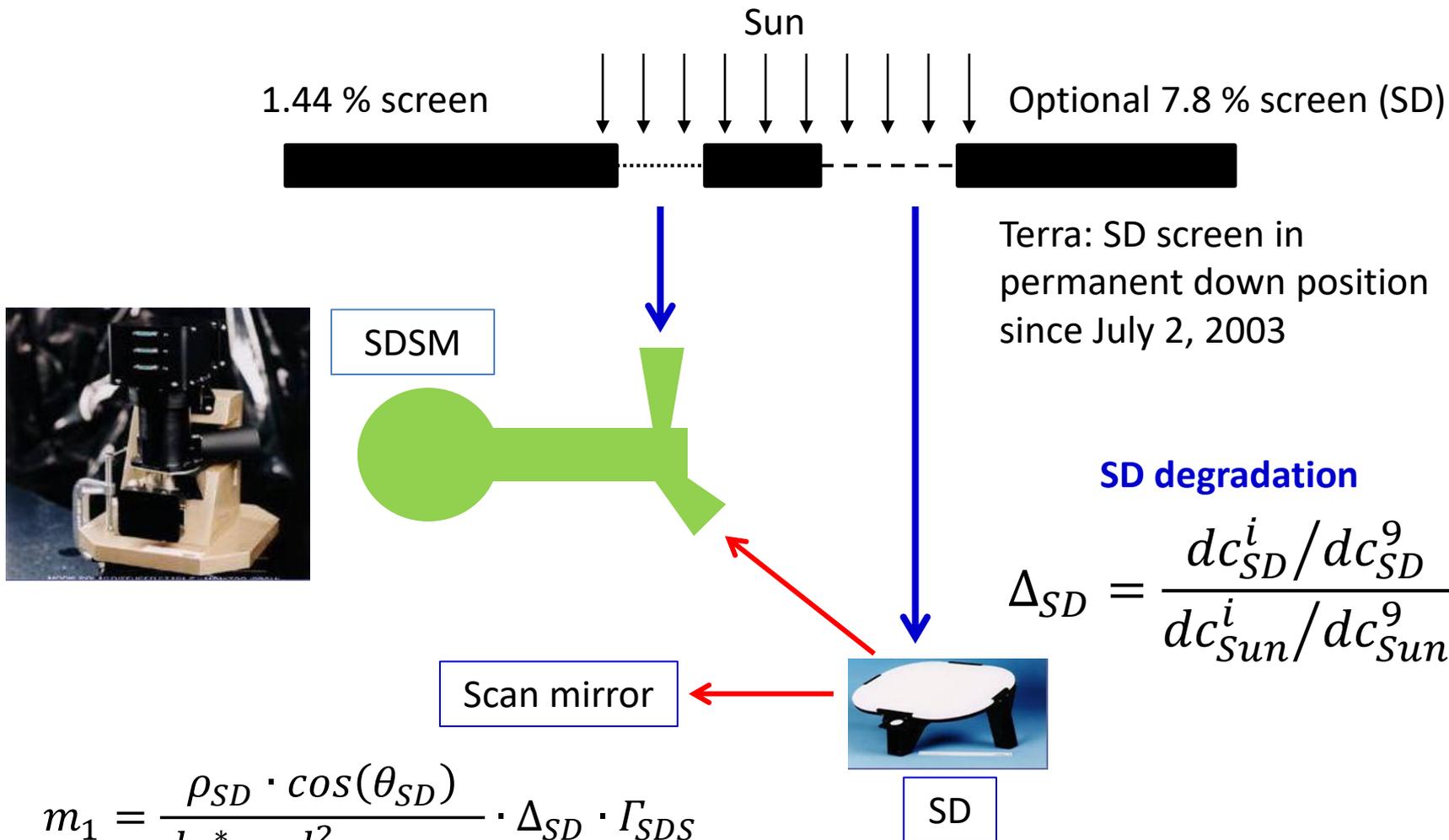
- Calibration Source

- SD/SDSM calibration
- Lunar observation
- EV mirror side (MS) ratios
 - SRCA MS ratios (previously used are not considered due to lamp failures)
- Response trending from EV targets





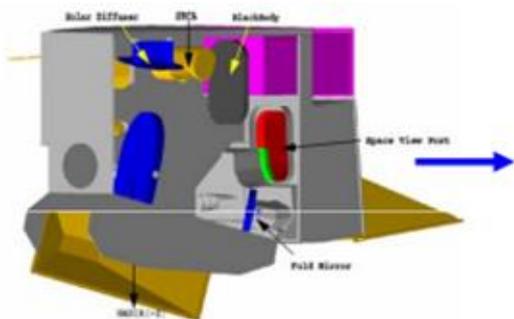
RSB SD Calibration



ρ_{SD} = BRF, dn_{SD}^* = Signal from SD (temperature and background corrected), Δ_{SD} = SD degradation, Γ_{SDS} = screen attenuation

RSB Lunar Calibration

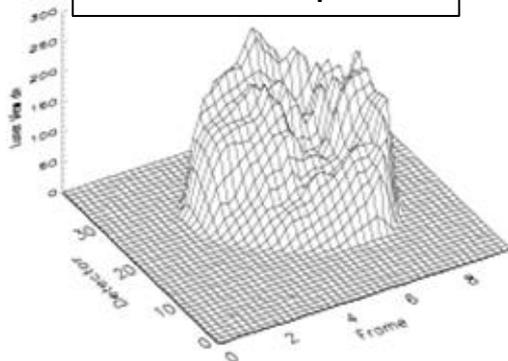
MODIS



Moon



MODIS Response



Near-monthly calibration
Phase angles between 55° - 56°

Lunar calibration coefficients

Bands 1-4, 8-12, 17-19

$$m_1^{moon} = \frac{f_{vg}}{\langle dn_{moon}^* \rangle}$$

Bands 13-16 (saturated)

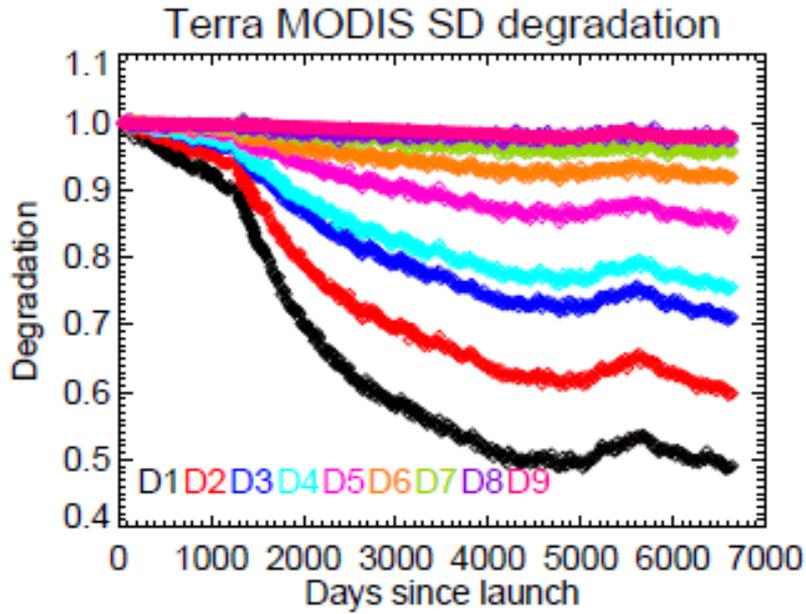
$$m_1^{moon} = m_{1,B18}^{moon} \cdot \frac{\langle dn_{Moon,B18}^* \rangle}{\langle dn_{Moon}^* \rangle}$$

View geometry correction

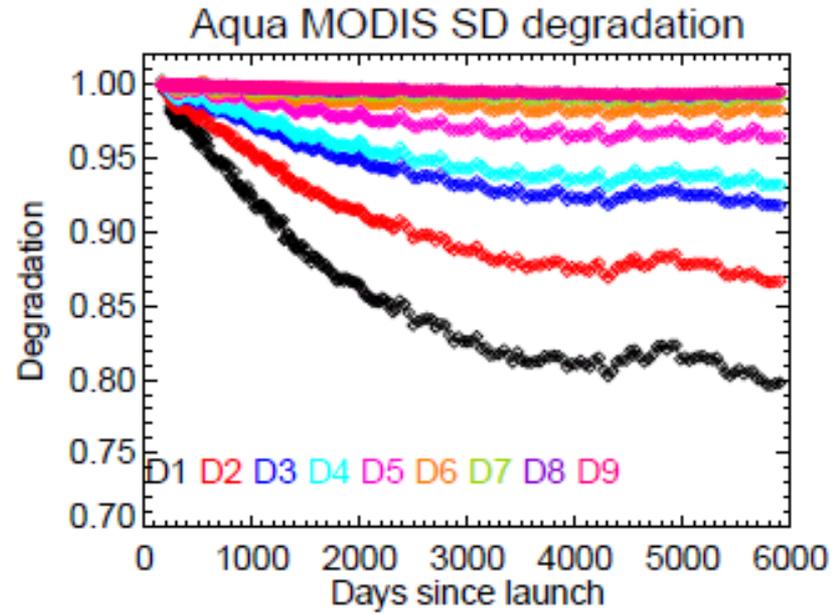
$$f_{vg} = \frac{f_{phase-angle} \cdot f_{libration} \cdot f_{oversampling}}{d_{Sun-Moon}^2 \cdot d_{Moon-MODIS}^2}$$



MODIS SD Degradation



Terra



Aqua

Increased degradation after Terra SD door anomaly on July 2, 2003. Larger SD degradation at shorter wavelengths for both instruments

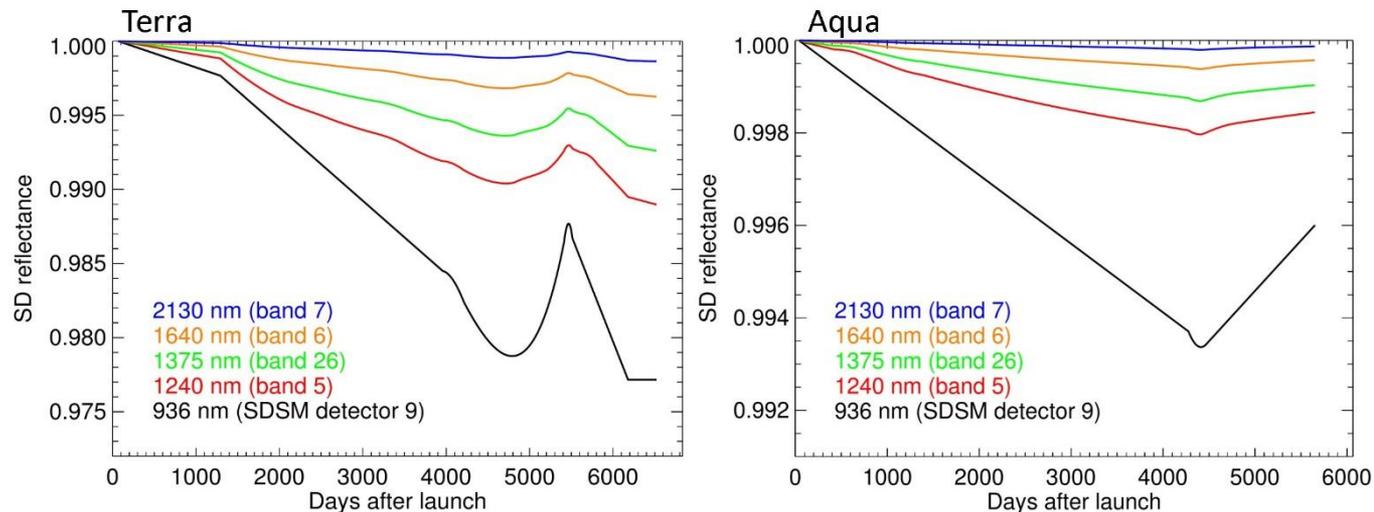
A special “fix” mode operation was performed for Aqua MODIS SDSM to verify the results observed in previous years



MODIS SD Degradation at SWIR wavelengths

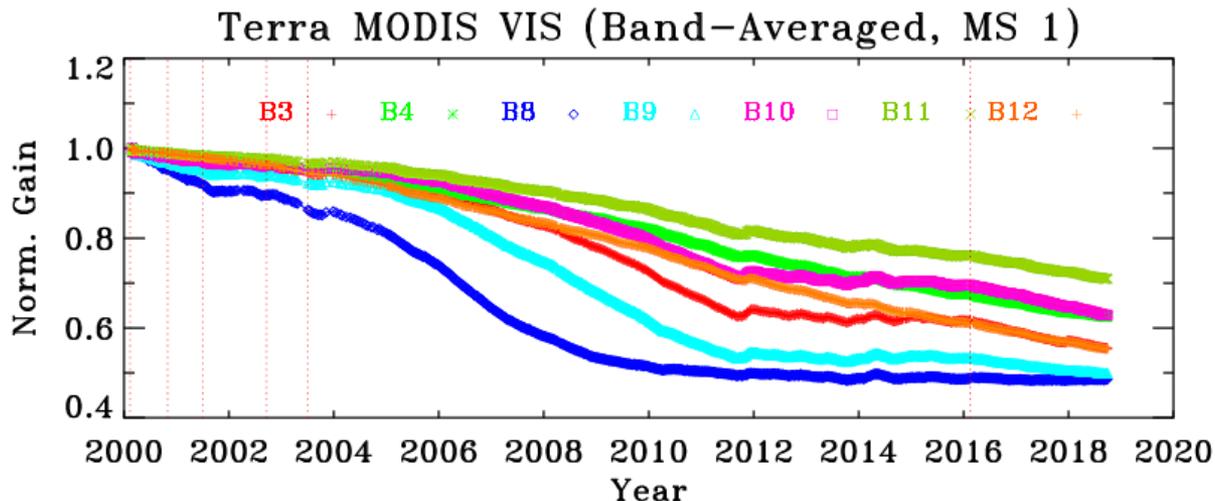


- The solar diffuser degradation at SWIR band wavelengths is not tracked by the SDSM, but can be significant (e.g. >1% for Terra band 5). Starting with January 2018 LUT updates, MCST updated the SD degradation at SWIR wavelengths.
- Previous Collection 6/6.1:
 - The long term reflectance trends of Earth targets were used to derive a linear correction coefficient for Terra band 5 (using desert sites) and Terra band 26 (using DCC). The other SWIR bands did not have any SD degradation applied.
- Forward Collection 6/6.1:
 - We estimate SD degradation at SWIR by performing a power law fit to the SD degradation calculated from SDSM detectors and extrapolating to the SWIR.



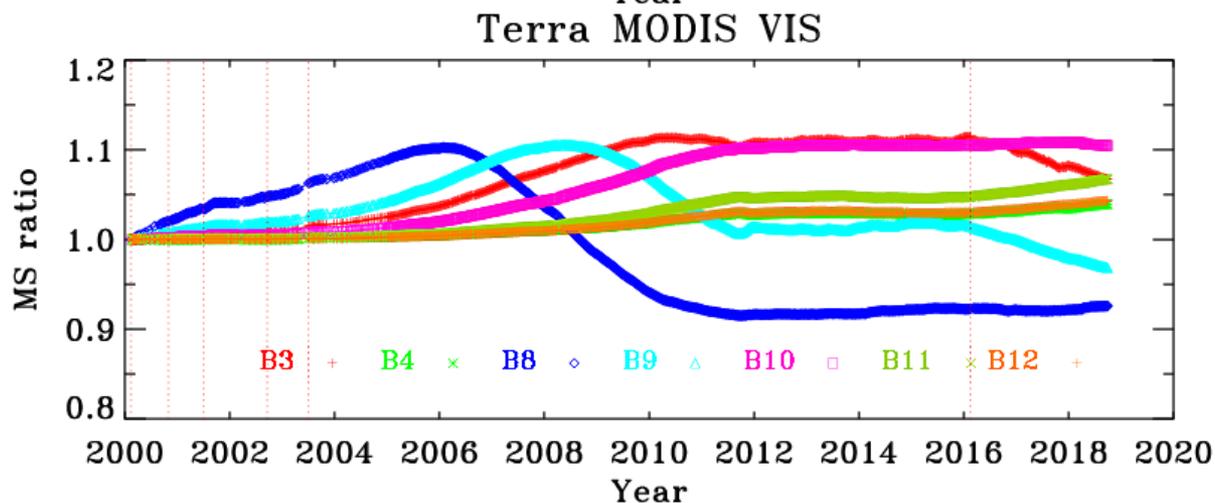


SD Gain Trending: Terra



Most change observed for short-wavelength bands

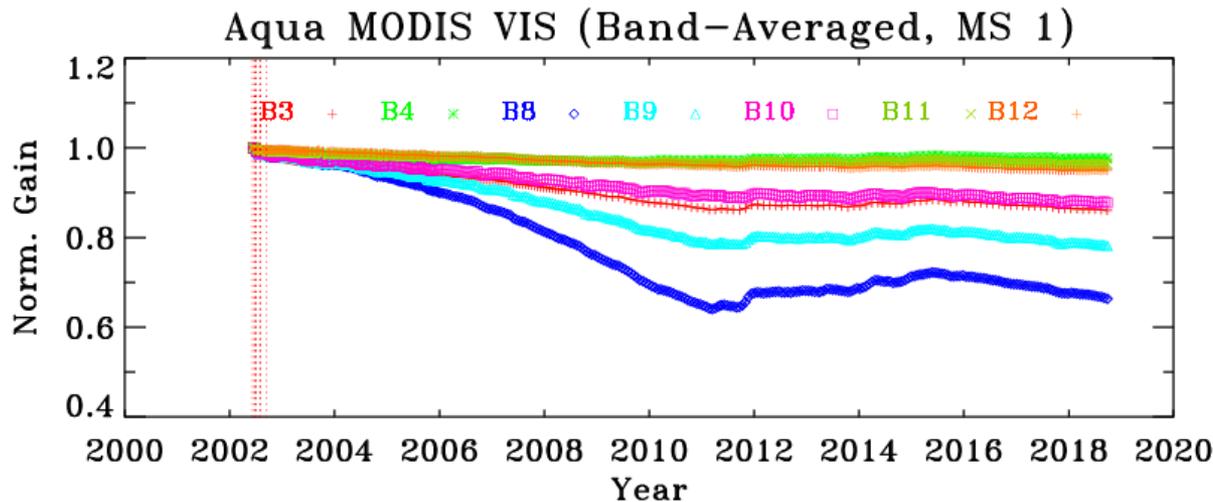
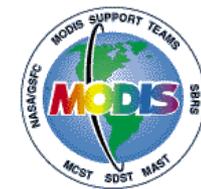
Band 8 (.412 μm) changes by over 50%



Terra VIS bands have a maximum mirror-side difference of about 11% at the SD AOI (Band 3 - .469 μm)

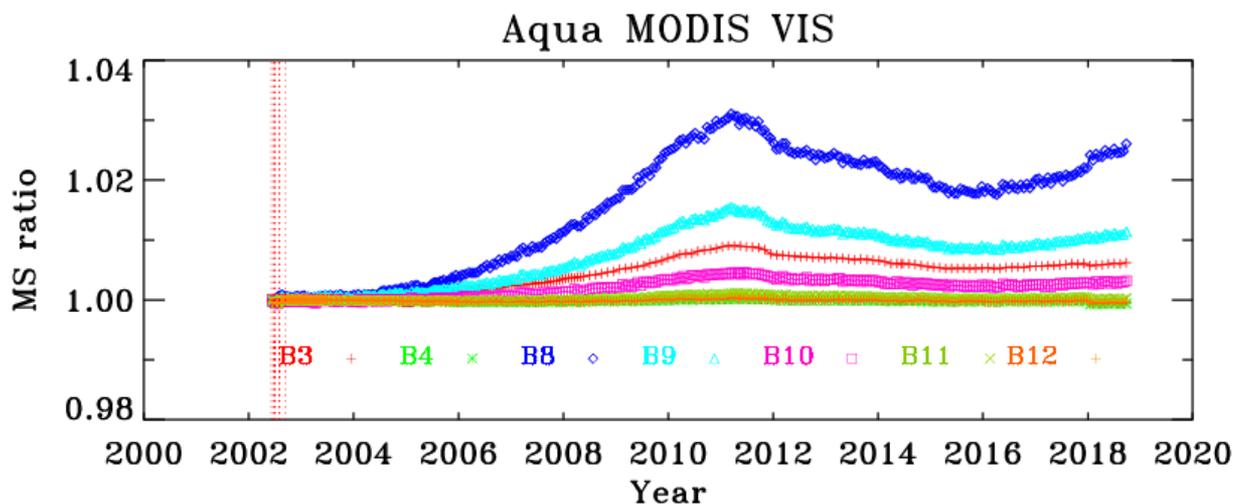


SD Gain Trending: Aqua



Most change observed for short-wavelength bands

Band 8 (.412 μm) maximum change is $\sim 40\%$



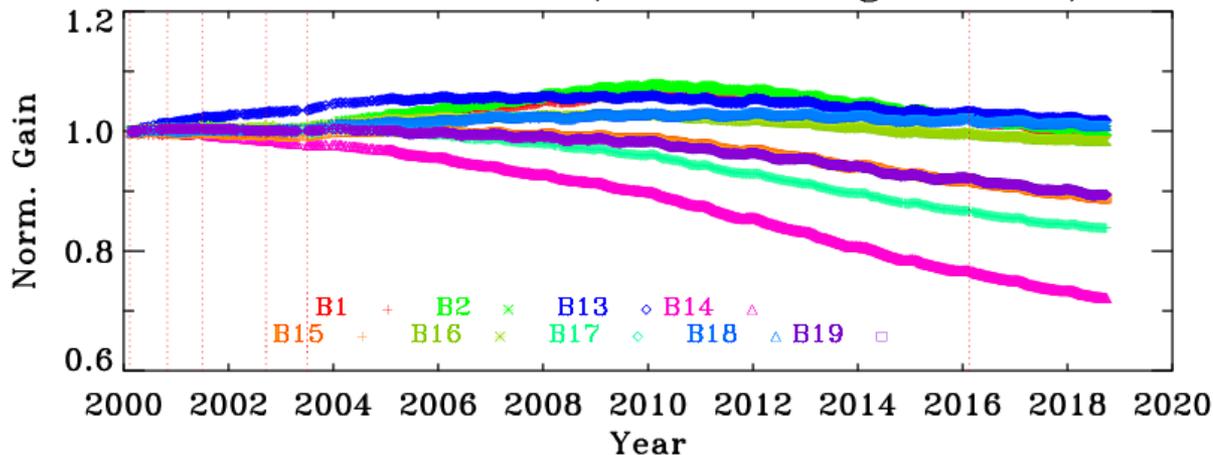
Aqua VIS bands have a maximum mirror-side difference of about 3% at the SD AOI (Band 8)



SD Gain Trending: Terra

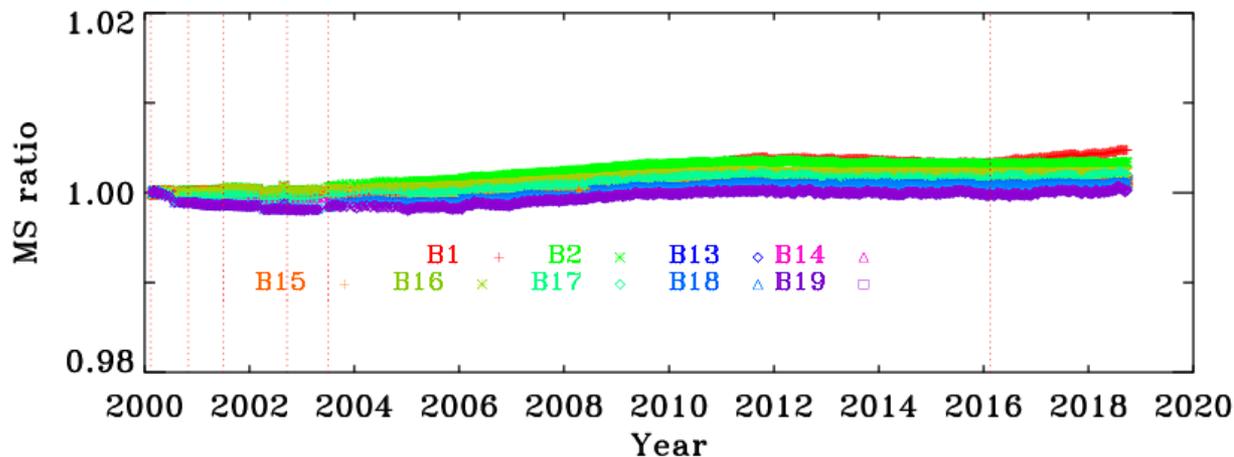


Terra MODIS NIR (Band-Averaged, MS 1)



Changes for most NIR bands are within 10%

Terra MODIS NIR



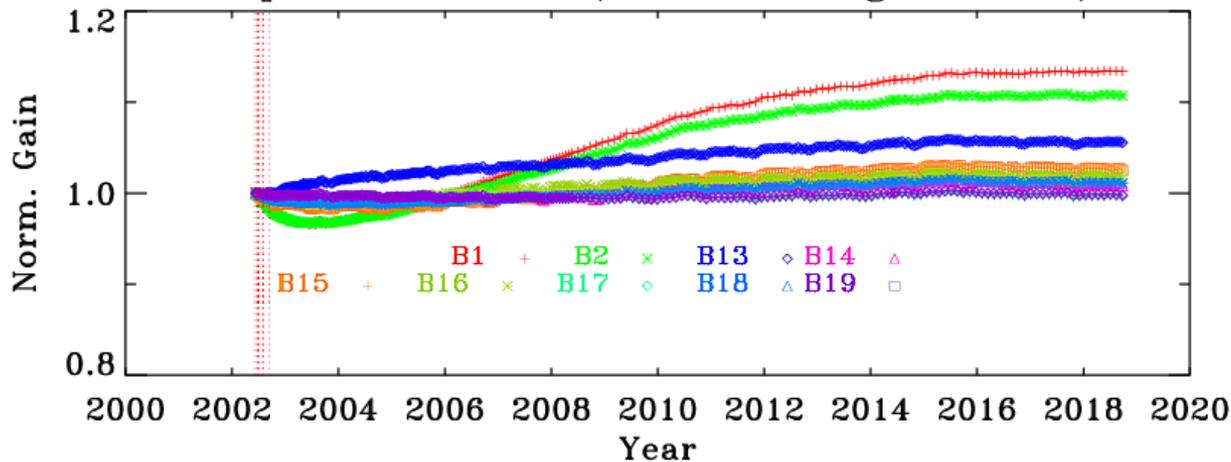
Mirror-side differences are <1%



SD Gain Trending: Aqua

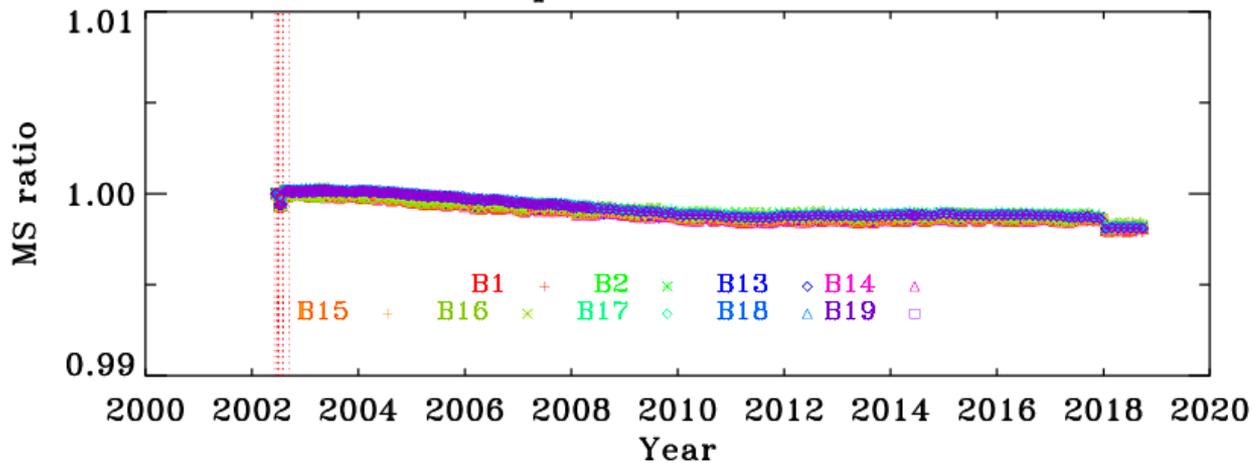


Aqua MODIS NIR (Band-Averaged, MS 1)



Changes for most NIR bands are within 6%

Aqua MODIS NIR



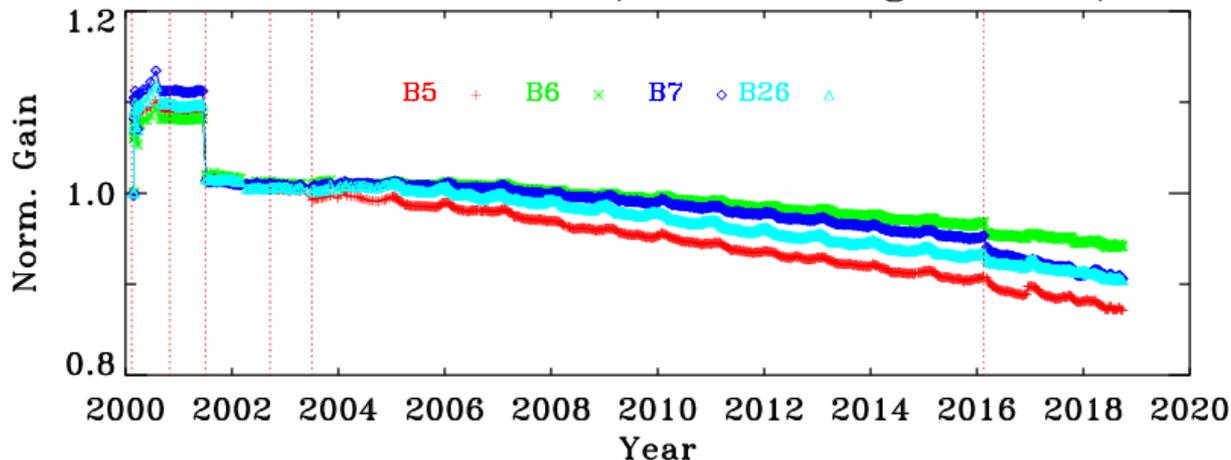
Mirror-side differences are <1%



SD Gain Trending: Terra

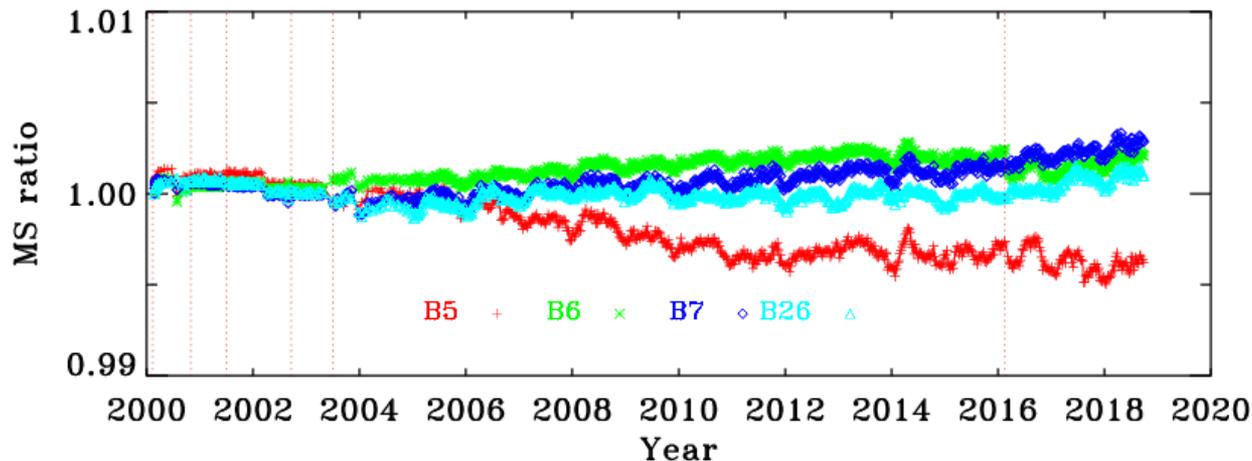


Terra MODIS SWIR (Band-Averaged, MS 1)



All SWIR bands change by < 10%

Terra MODIS SWIR



Mirror-side differences are < 1%

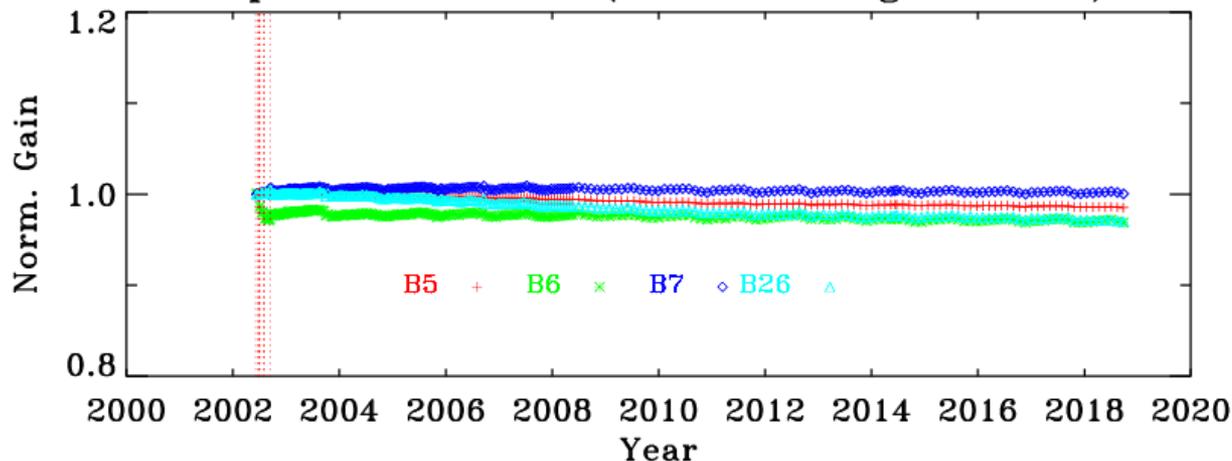
* Noisy and inoperable detectors excluded



SD Gain Trending: Aqua

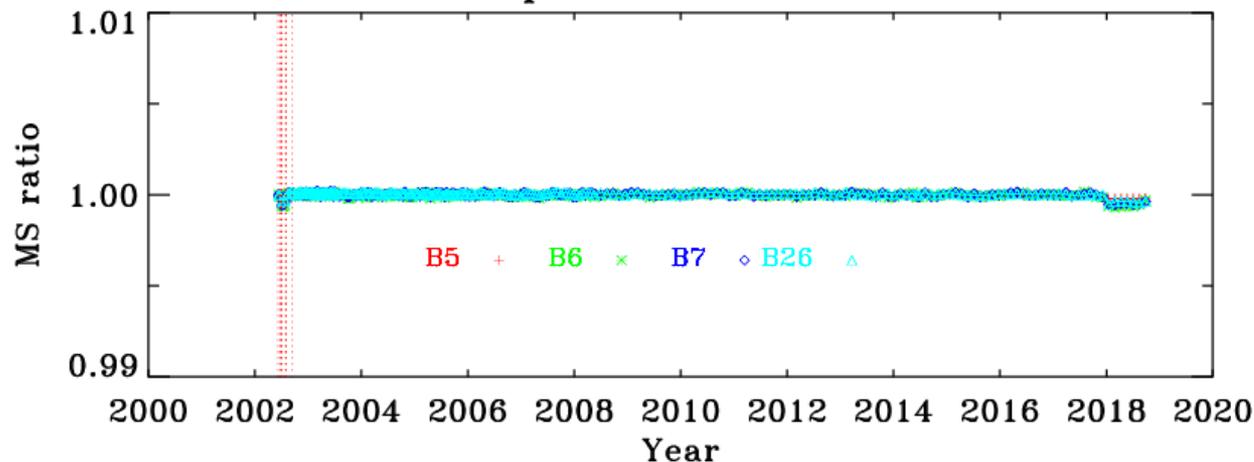


Aqua MODIS SWIR (Band-Averaged, MS 1)



All SWIR bands
change by < 3%

Aqua MODIS SWIR

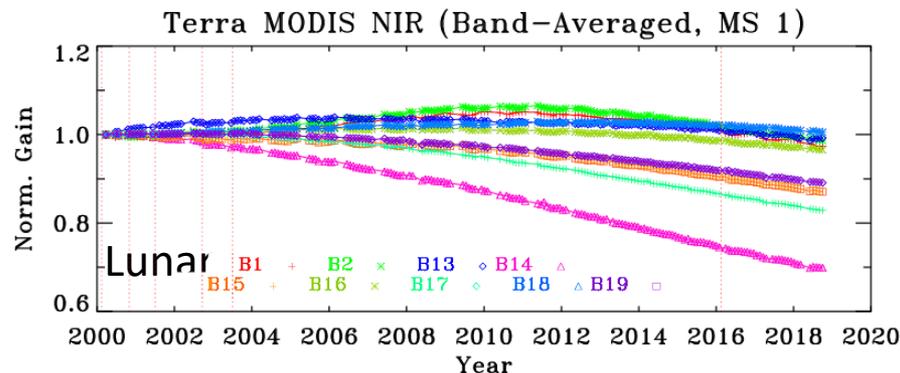
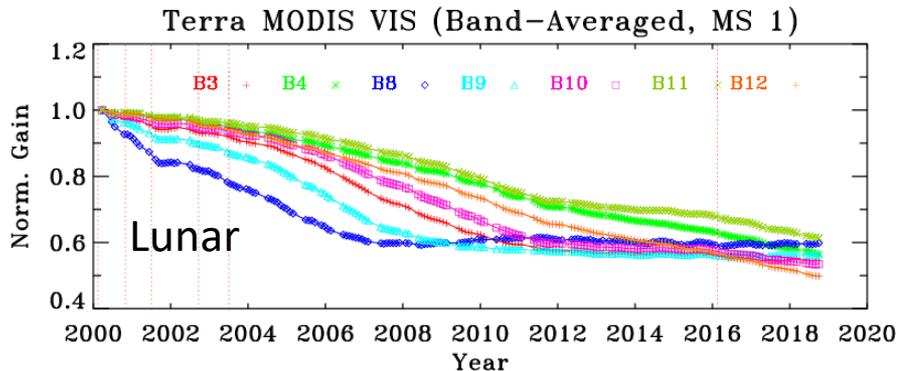
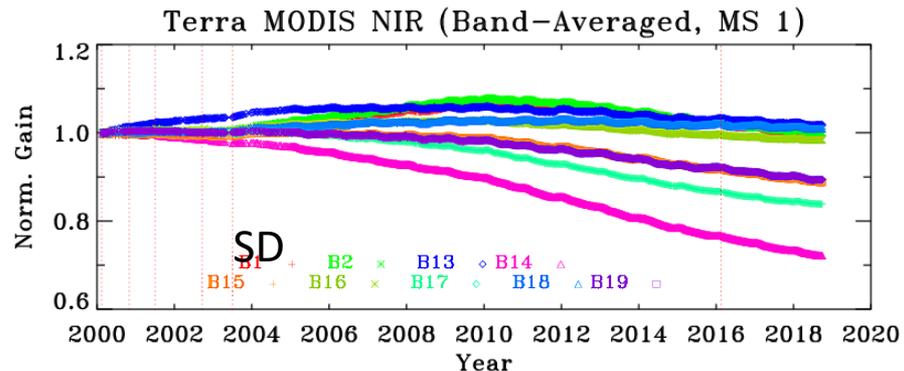
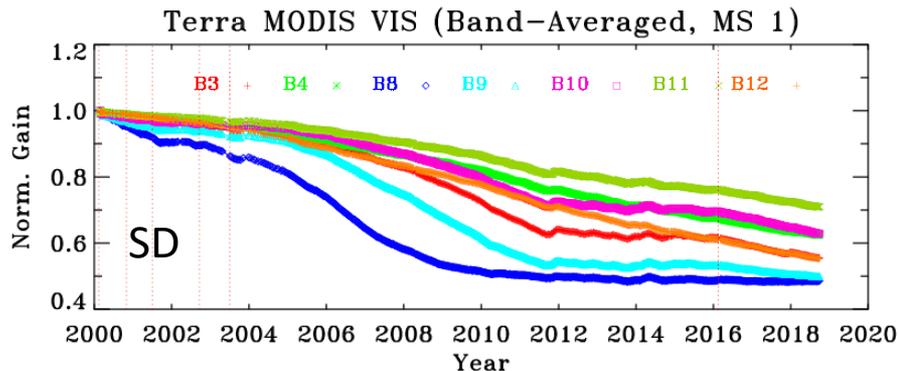
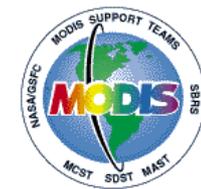


Mirror-side
differences are
<1%

* Noisy and
inoperable detectors
excluded



Terra MODIS SD & Lunar Gain Trending

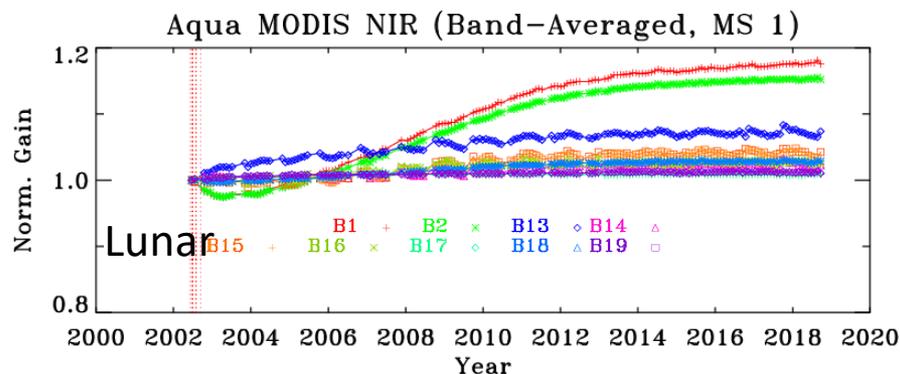
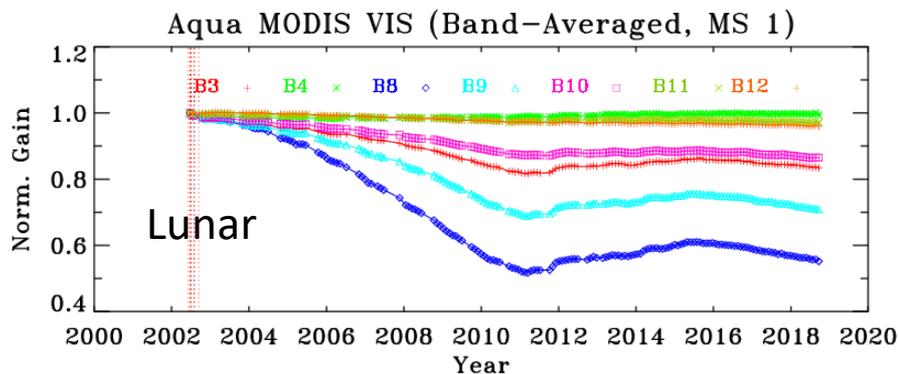
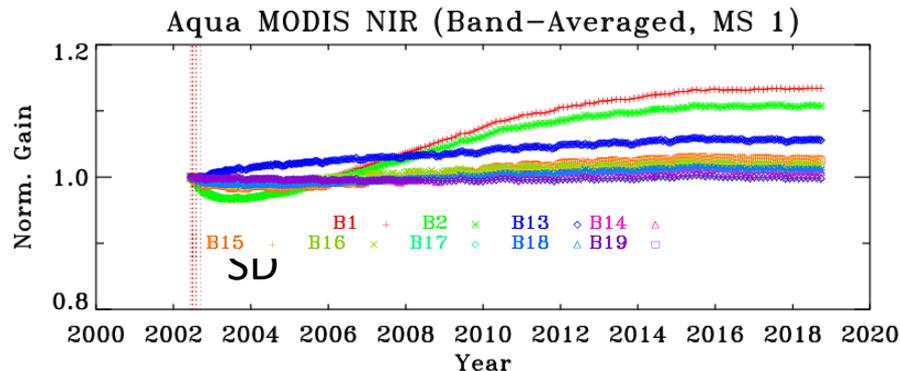
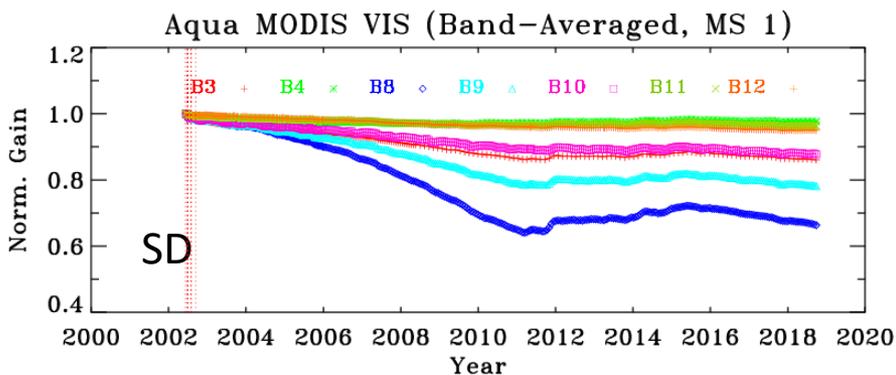
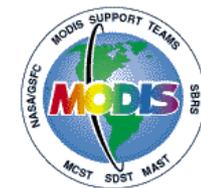


SD & Lunar measurements used to derive the on-orbit RVS change

SD AOI = 50.25° Lunar (SV Port) AOI = 11.2°



Aqua MODIS SD & Lunar Gain Trending

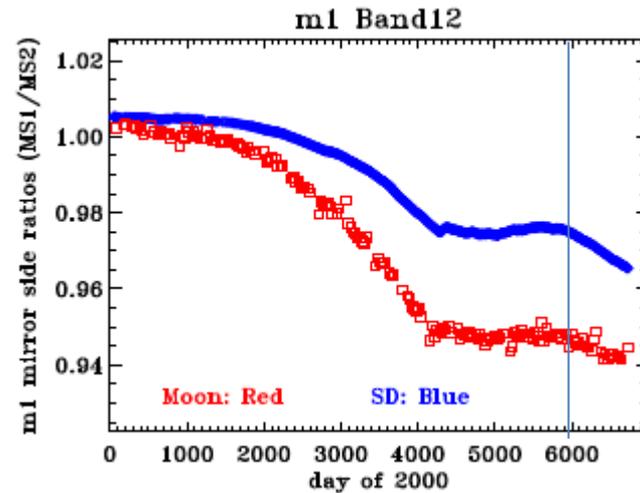
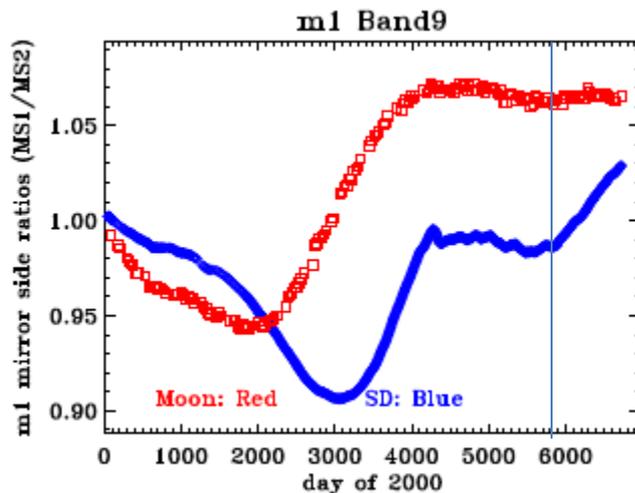
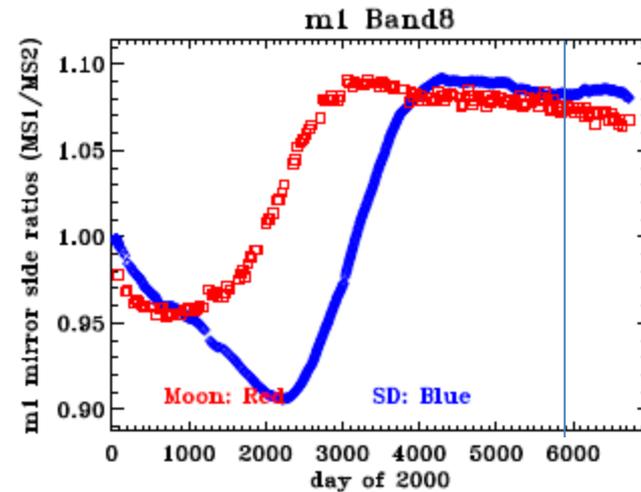
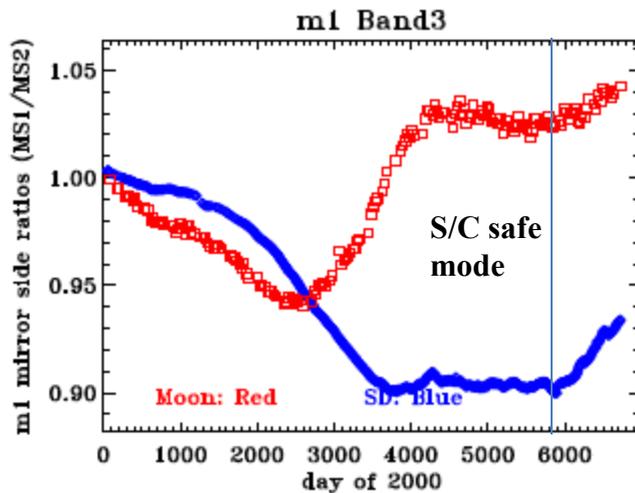


SD & Lunar measurements used to derive the on-orbit RVS change

SD AOI = 50.25° Lunar (SV Port) AOI = 11.2°



Terra MODIS VIS Mirror Side Difference

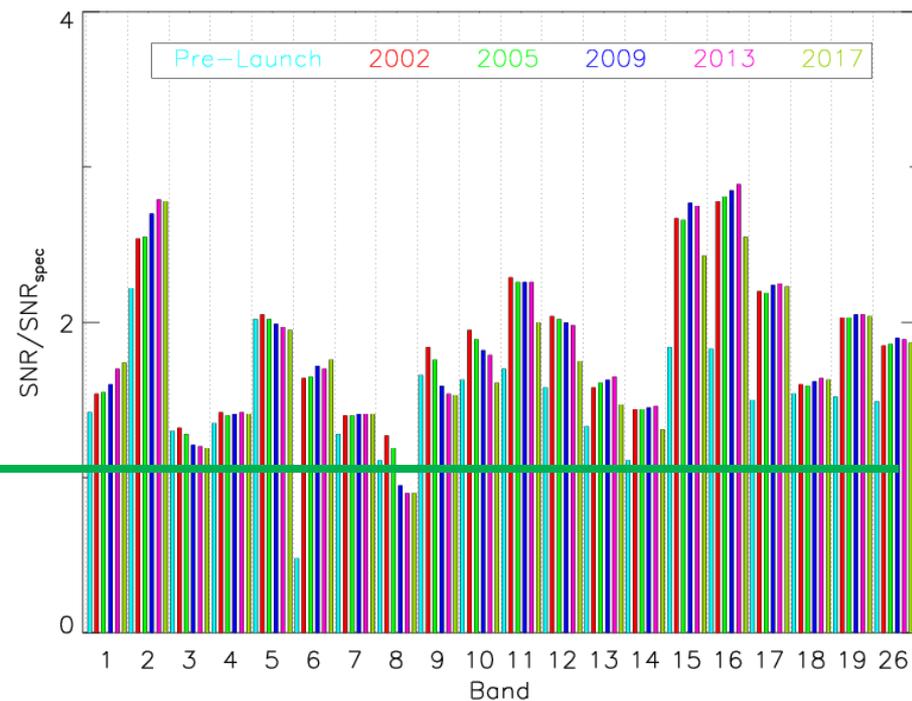
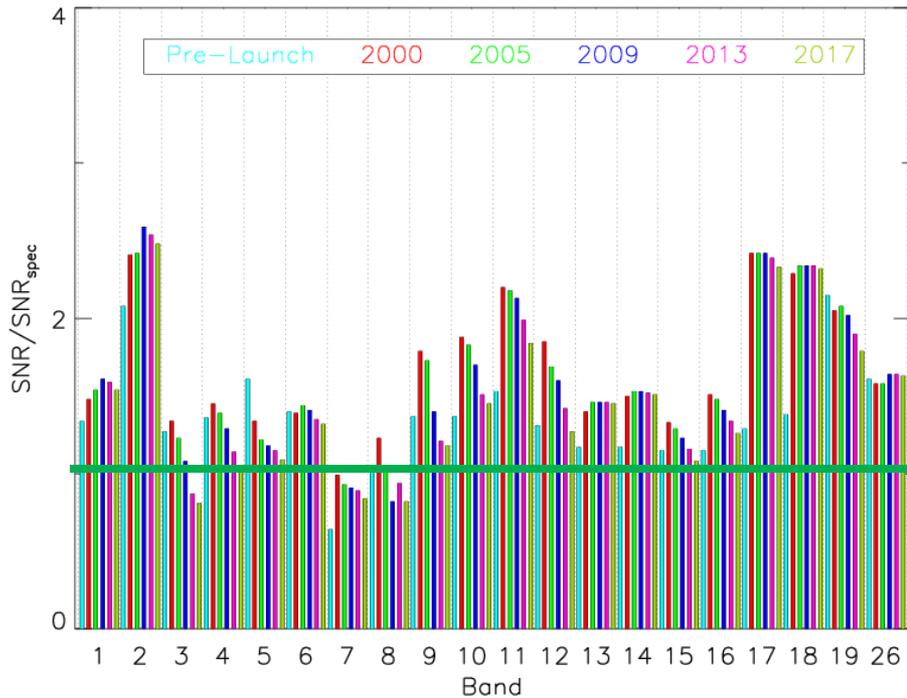


SD AOI = 50.25° Lunar (SV Port) AOI = 11.2°

Sharp changes in the MS ratio trends after the S/C safe mode (2016)



MODIS RSB SNR Bar-Charts

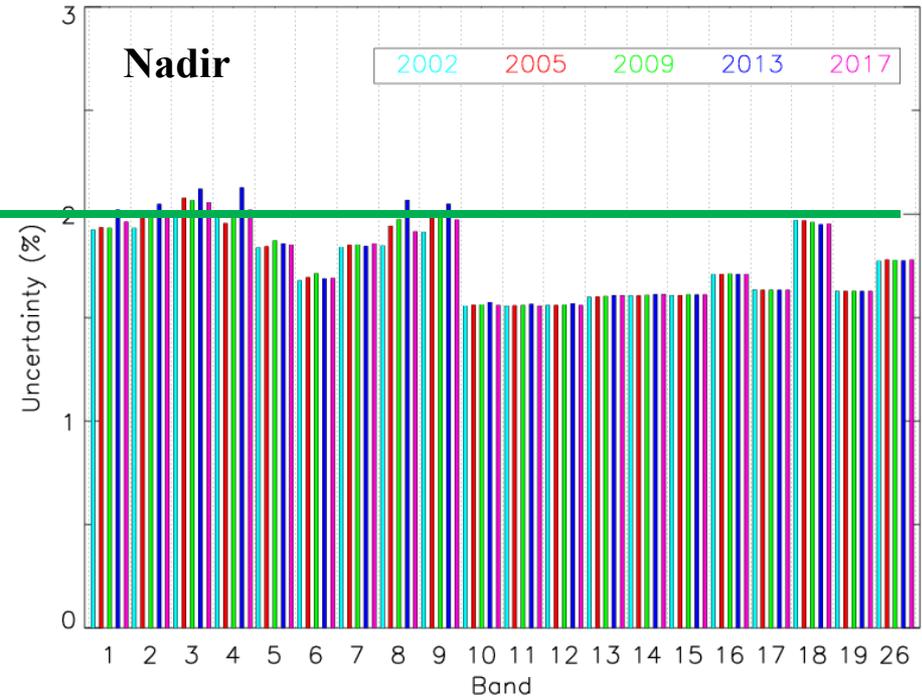
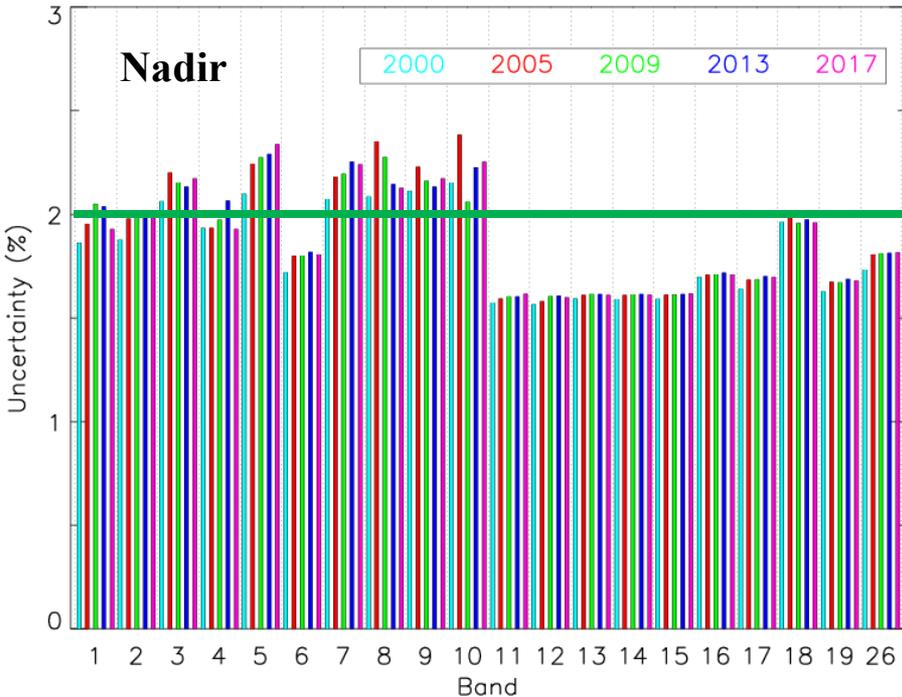


Most bands continue to meet the specification.

- Known issues with the inoperable/noisy detectors in Aqua band 6.
- Decreased responsivity for some short wavelength RSB (Terra bands 8, 9, 3, Aqua band 8)
- Terra band 7 SNR known to be below specification since launch



MODIS RSB Uncertainty Trends



Most bands continue to meet the specification.

- Additional uncertainty associated with the bands that employ EV-based RVS characterization approach (Terra bands 1-4,8-10 and Aqua bands 1-4, 8,9)
- On-orbit changes in the polarization sensitivity is also a contributing factor.



RSB Calibration Special Topics



Recent MCST activities to improve RSB calibration:

- We have been investigating several ways to improve on-orbit RVS characterization:
 - Apply polarization correction for Terra VIS bands to improve gain derivation at large scan angles.
 - Use an inter-band approach that relies on relative trends of ocean data to derive RVS for Terra bands 11 and 12
 - Alternative methods of deriving RVS from desert sites
 - RVS derived from DCC measurements
 - Introduce on-orbit RVS for SWIR bands (which still use pre-launch RVS) using SD and lunar data
- Improvements to OOB/crosstalk corrections for SWIR bands
- Evaluate impact of changing RSR



Terra Polarization correction



The polarization sensitivity of scan mirror has impacted performance of Terra MODIS short-wavelength RSB

- C6.1 L1B does not include any correction for polarization effects

Current mitigation strategy for L2 products

- NASA OBPG has derived polarization correction coefficients from a cross-cal with SeaWiFS/Aqua MODIS over ocean targets
- For land products, use the OBPG polarization coefficients to generate a L1B_PC product followed by de-trending to correct gain for desert sites

MCST activities for next Collection

- Apply polarization correction in derivation of gain from desert sites for Terra bands 8, 9, 3.
- **Goal: Improve accuracy of L1B product and forward-predicted gain. Reduce the magnitude of downstream gain (M_{11}) and de-trending corrections.**



Terra Polarization correction



Current polarization mitigation strategy

For ocean products: NASA OBPG performs a xcal with SeaWiFS/Aqua to Terra L1B to generate the coefficients for Terra polarization correction

$$L_t = \frac{L_m}{M_{11}} - m_{12}Q - m_{13}U$$

L_t : true radiance, L_m : measured radiance, M_{11} : gain correction

➤ Shihyan Lee

For land products:

- Use these M_{11} , m_{12} , and m_{13} to correct the long-term reflectance time-series of MODIS RSB from the desert sites: L1B_PC
- The Q and U are site specific
- De-trending applied to correct for residual drifts

➤ Alexei Lyapustun and Yujie Wang



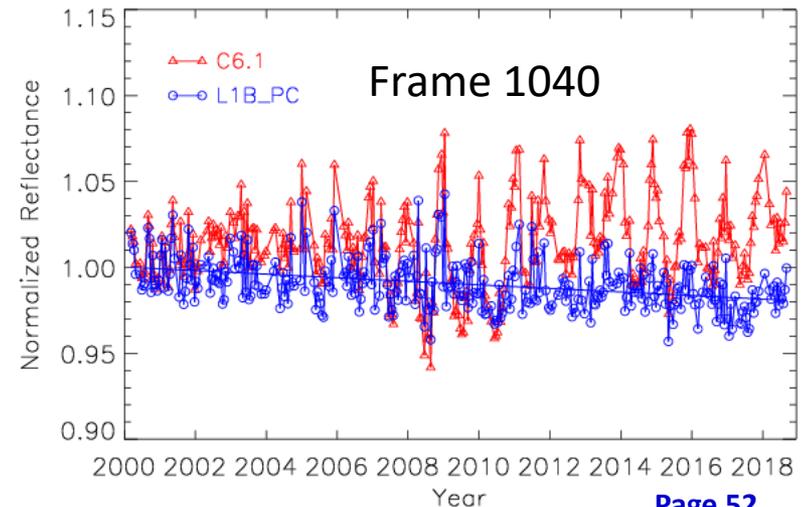
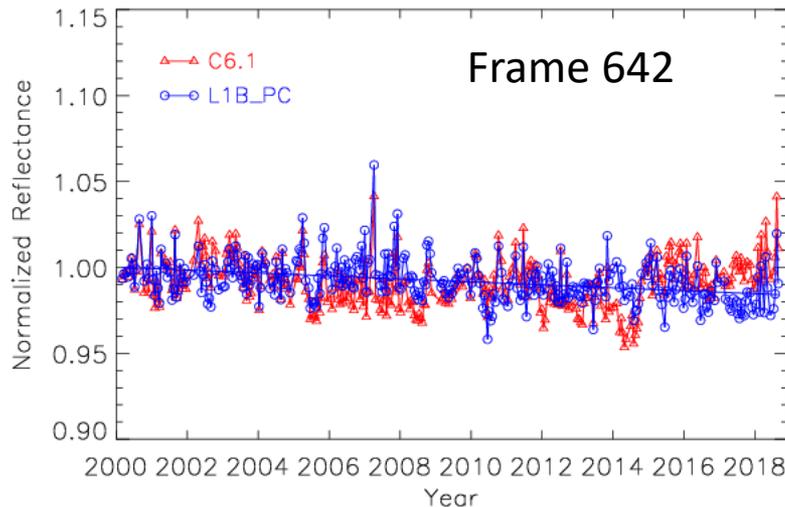
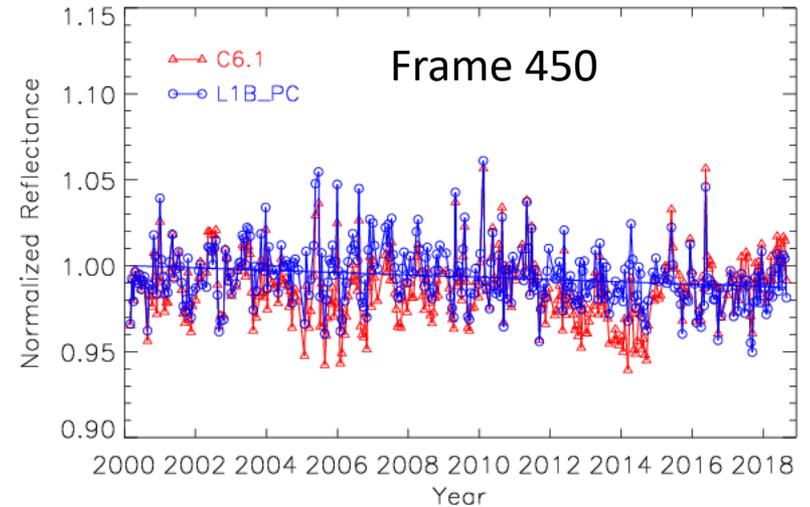
Terra Polarization correction



Current L1B and L1B_PC reflectance trends

- Large oscillations in C6.1 L1B due to uncorrected polarization
- L1B_PC corrects for polarization, but has drift that needs to be corrected using de-trending. Drift may be due to difference between ocean-derived and desert-derived gain.

Band 8 (412 nm) – Libyan desert





Terra Polarization correction

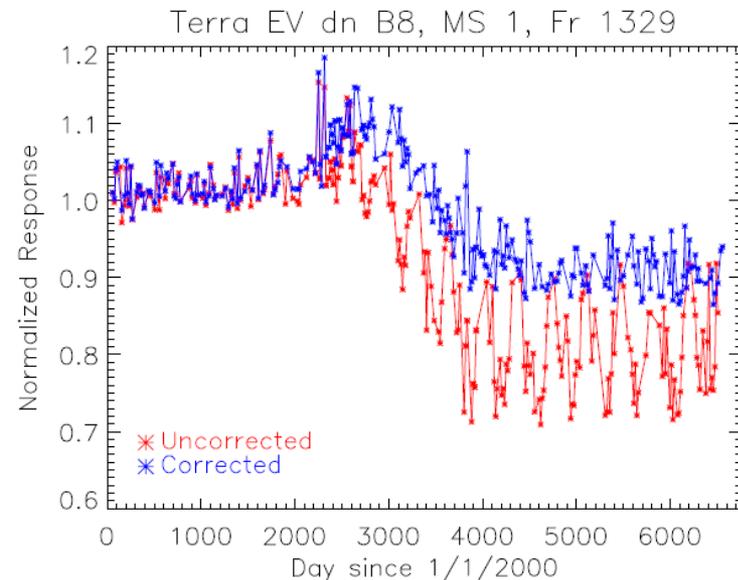
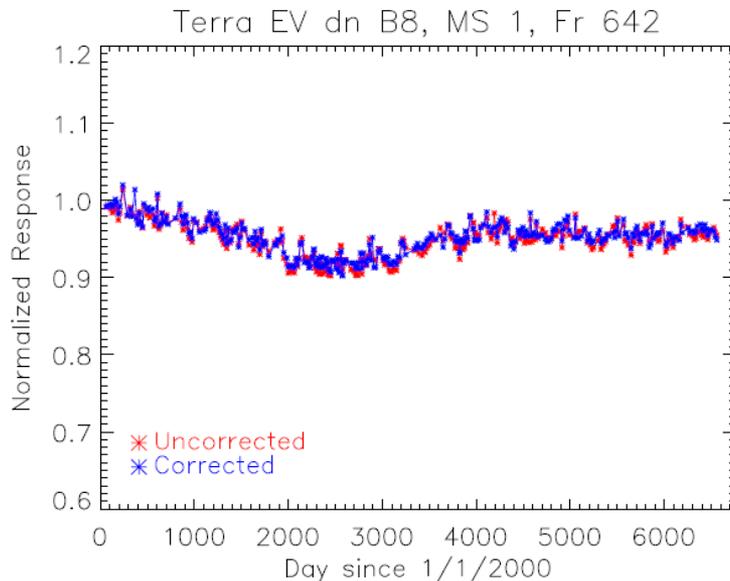


MCST approach for next Collection

Calibrated gains (m_1/RVS) derived from desert trends

- Derive BRDF corrected reflectance, ρ_{BRDF} , for desert using first few years of data and the time-dependent OPBG polarization coefficients m_{12} and m_{13}
- Then derive the gain from the measured dn^* and the polarization and BRDF corrected desert reflectance

$$gain = \frac{dn^* d_{ES}^2 / \cos(\theta)}{\rho_{BRDF} + m_{12}Q + m_{13}U}$$





Terra Polarization correction

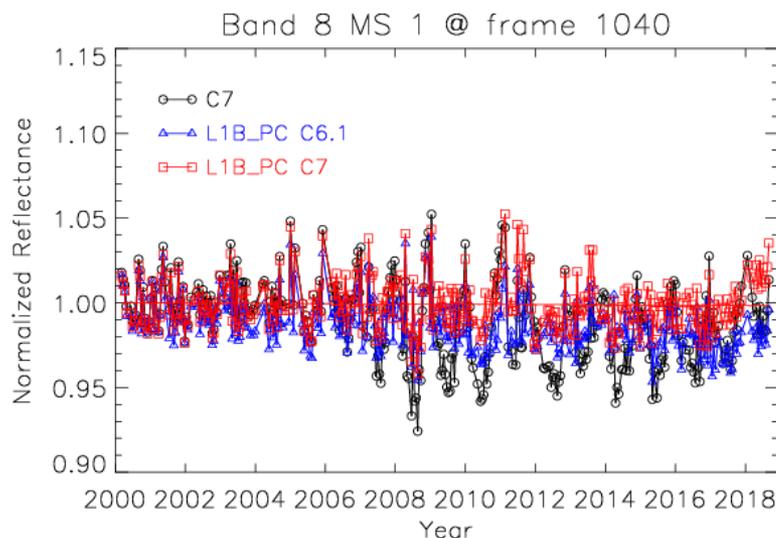
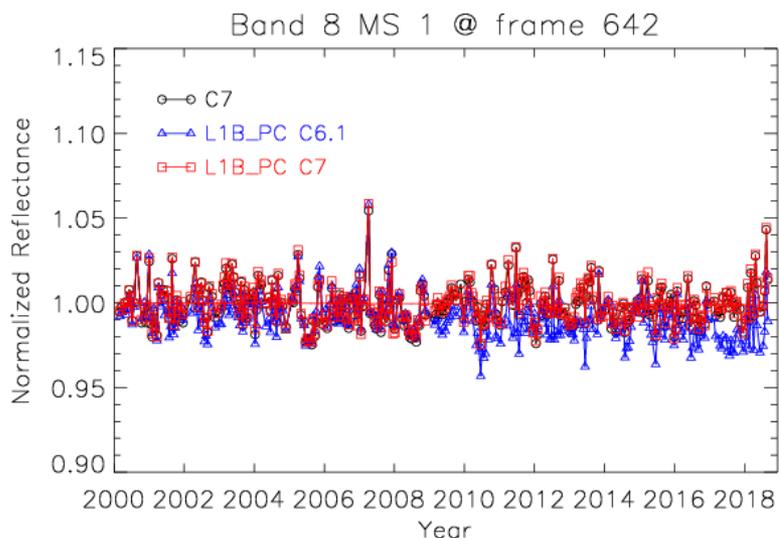
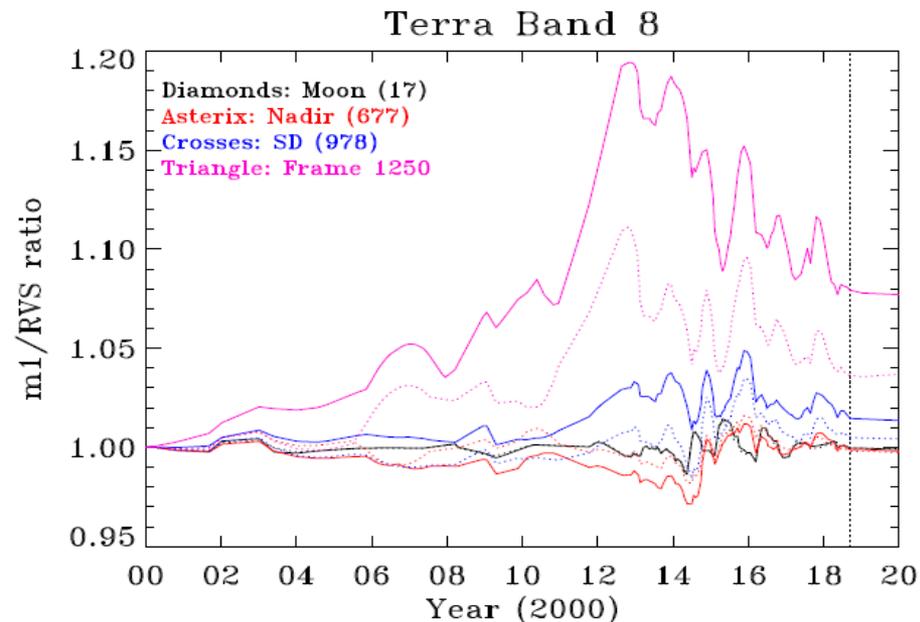


Compare "C7" gain trend with C6.1 gain trend

- Results similar to M_{11} gain trend from OBPB cross-cal

Compare reflectance trends

- C7 L1B better than C6.1 L1B
- C7 L1B_PC has less drift compared to C6.1 L1B_PC





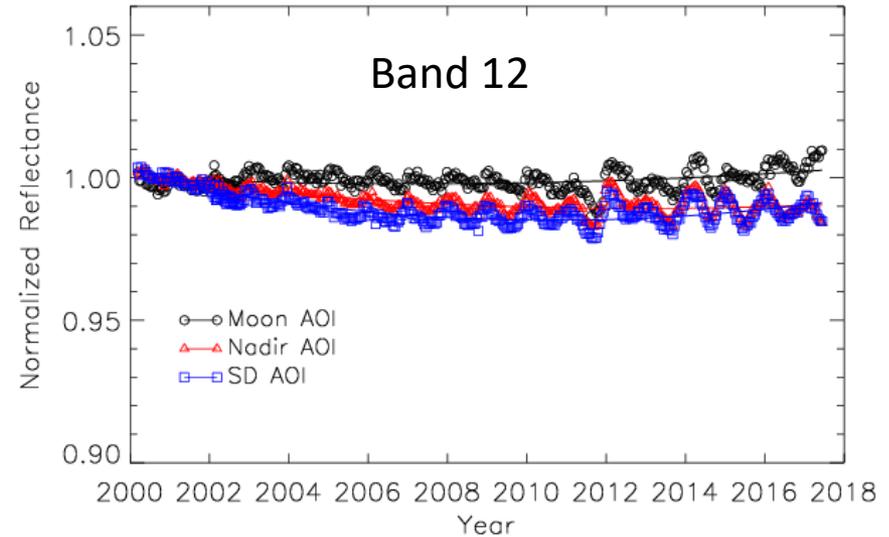
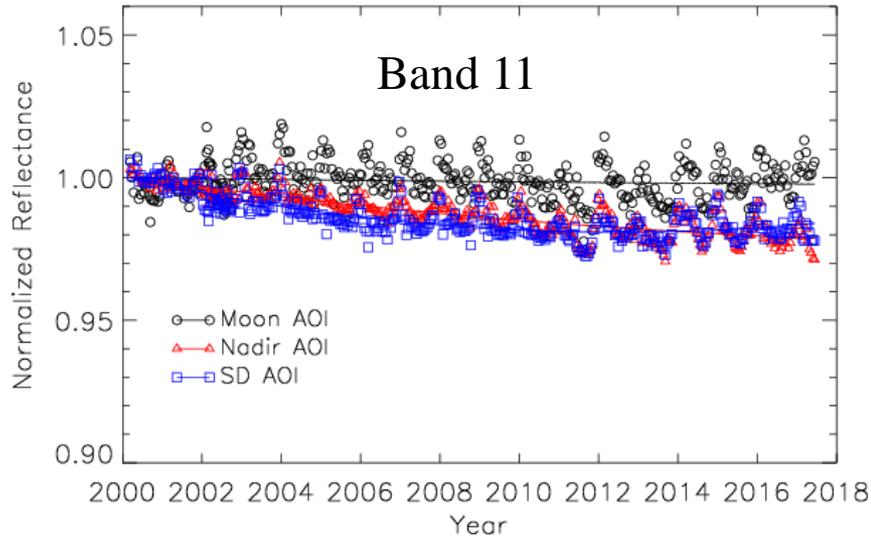
Terra B11-12: Inter-band approach



- C6/C6.1 L1B currently uses EV-based m_1 and RVS for Terra bands 1-4, 8-10. This approach utilizes desert measurements to supplement the on-orbit gain derived from the solar and lunar measurements
 - This approach is necessary for an accurate characterization of the RVS , therefore eliminating the long-term reflectance drifts observed in previous versions
- As the gain continues to degrade, we would like to extend the EV-based approach to other RSB, e.g. bands 11 and 12
 - The desert-based approach is not viable for these (and other high-gain ocean bands) as they saturate while viewing the high-radiance desert.
 - Using ocean targets to derive direct trends is challenging because the response is dominated by Rayleigh scattering and a comprehensive need for atmospheric correction is required
- Proposal: An inter-band calibration approach using band 4 (spectrally overlapping) as a reference to monitor the long-term reflectance for bands 11 and 12.
 - The band 4 gain is calibrated from desert PICS approach, and reflectance comparisons with b11 and b12 over ocean granules are used to derive gain for b11 and b12.



Terra B11-12: Inter-band approach



- Long-term drift observed at nadir and SD AOIs for both bands with band 11 showing up to 2% drift, demonstrating the need for EV-based calibration of these bands.
 - No impact expected on the OBPG products as M_{11} factor in the polarization correction accounts for any observed residual drifts.
- Path Forward: MCST has delivered a special LUT including these corrections based on inter-band calibration to OBPG for evaluation and feedback after which a decision will be made to include these in forward production of C6.1

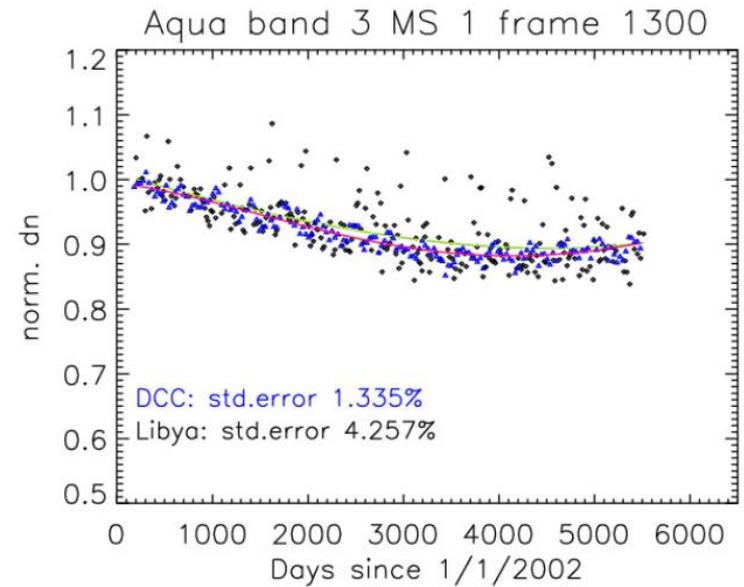


Alternative RVS algorithms



MCST has investigated various alternative ways to derive RVS using Earth targets

- Alternative algorithm with Libyan desert data
 - Derive AOI-dependence (RVS) from a single desert site, Libya 4. Use moon as anchor point for on-orbit gain change. Tested for MODIS **bands 1-4, 8, 9**.
 - Using lunar gain reduces reliance on desert site invariance. Single-site approach may be more attractive during future de-orbiting phase of Terra and Aqua missions.
 - Results agree with C6.1 approach to <2%
- DCC-based RVS
 - We have developed our own DCC analysis and used it to derive on-orbit gain for MODIS **bands 1, 3, and 4**.
 - Signal trends from DCC targets can have lower noise than trends from desert PICS, particularly at large AOI.
 - Results agree with desert approach to <2% in most cases





On-orbit RVS for SWIR bands



C6.1 L1B (and all previous collections) uses pre-launch RVS for SWIR bands

- But recent evaluations with desert and DCC suggest there may be on-orbit changes to RVS for some SWIR bands

MCST plan

Derive on-orbit RVS for SWIR bands using same 2-point approach as NIR bands

- Solar diffuser AOI
 - SD degradation determined by extrapolating SDSM results to longer wavelength using a power-law fit.
- SV AOI
 - Gain at SV AOI derived from scheduled lunar observations using improved algorithm

T. Wilson, A. Angal, A. Shrestha, X. Xiong, Proc. SPIE **10423**, 1042313 (2017)

Evaluate effectiveness of RVS using desert and DCC trends.

Preliminary results are being studied. A challenge is properly correcting for SWIR OOB/xtalk through all mission configuration changes.



Terra SWIR xtalk improvements



MODIS SWIR bands (5-7 and 26) have a known issue related to electronic crosstalk and OOB leak identified during prelaunch characterization

- A correction to m_1 based on night-time-day-mode acquisitions has been applied since early mission. Correction employs band 28 as reference band (Aqua MODIS uses band 25 as reference)

After the Feb, 2016 safe mode, the Terra MODIS PV LWIR bands showed increased impacts due to electronic crosstalk.

- Lunar-based correction applied in C6.1 (entire mission) to mitigate the impacts for the PV LWIR bands
- But un-corrected band 28 signal still used to calculate SWIR band m_1

We are evaluating multiple options to improve mitigation of SWIR xtalk

- Correction derived from lunar observations

T. Wilson, X. Xiong, Proc. SPIE **10785**, 1078546 (2018)

- Correct band 28 signal for PV LWIR xtalk before deriving SWIR correction
- **Use band 25 as reference band in Terra MODIS SWIR correction →**

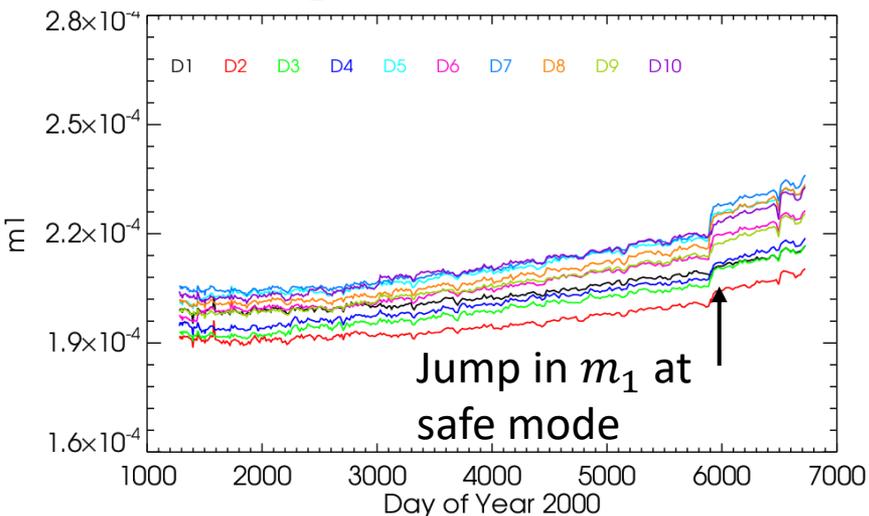
X. Xiong, A. Angal, Y. Li, Proc. SPIE **10781**, 1078151 (2018)



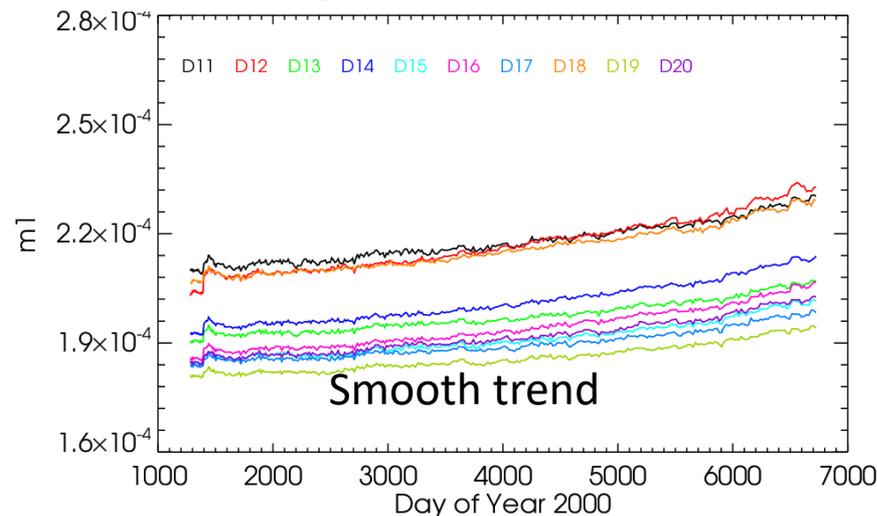
Terra SWIR xtalk improvements



B7 (sf2) m_1 trends with B28 reference

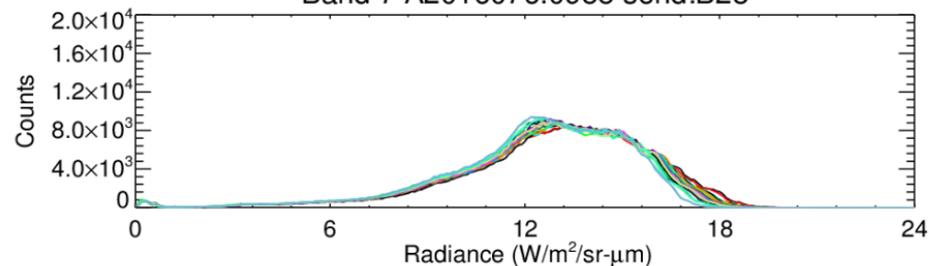


B7 (sf2) m_1 trends with B25 reference

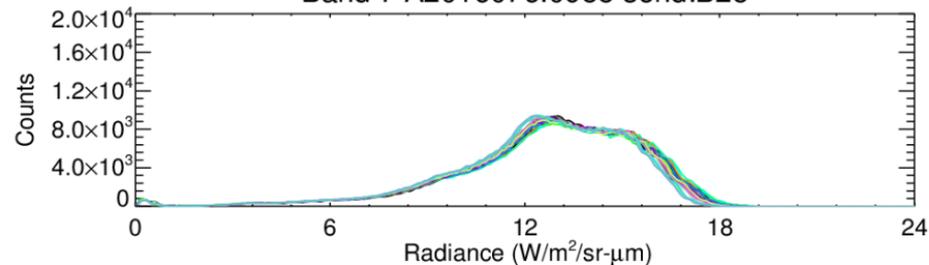


- Band 7 shows smoother m_1 trends and less detector striping for images after 2016 safe mode
- Bands 5 and 6 show similar improvements

Band 7 A2016076.0955 send:B28



Band 7 A2016076.0955 send:B25





On-orbit RSR changes

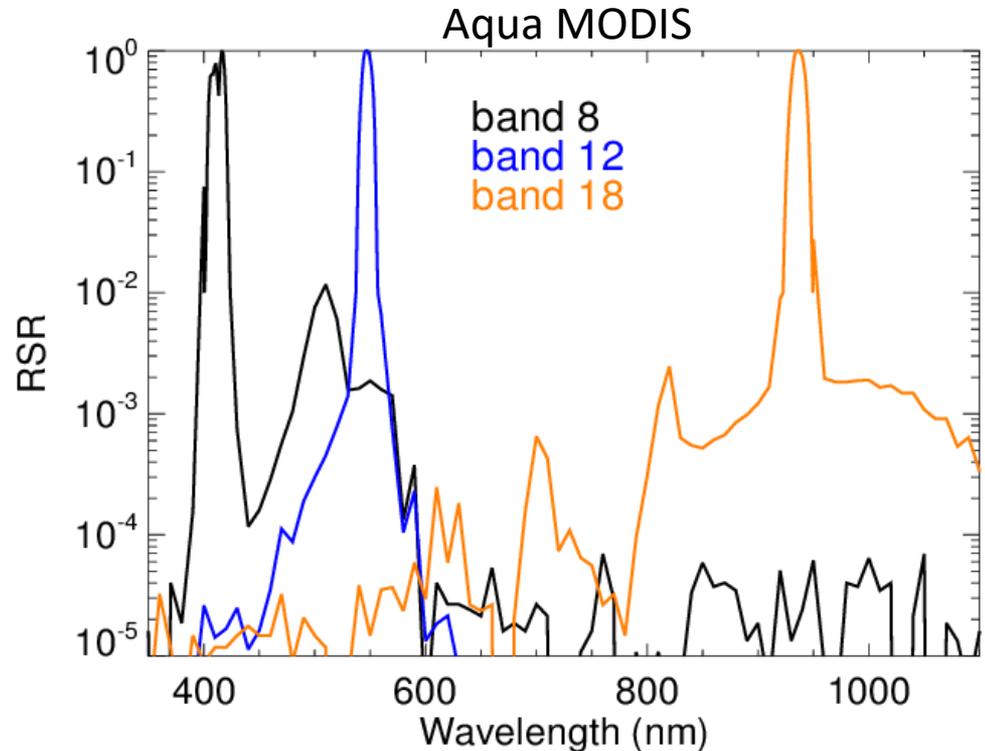


Relative spectral response of each band (in-band response and out-of-band response) measured prior to launch.

L1B calibration uses in-band pre-launch RSR only

RSB RSR can change on orbit. How does changing RSR affect calibration?

- 1) Consider in-band RSR changes as measured by SRCA
- 2) Consider broadband RSR changes due to scan mirror degradation ('modulated RSR')





On-orbit RSR changes



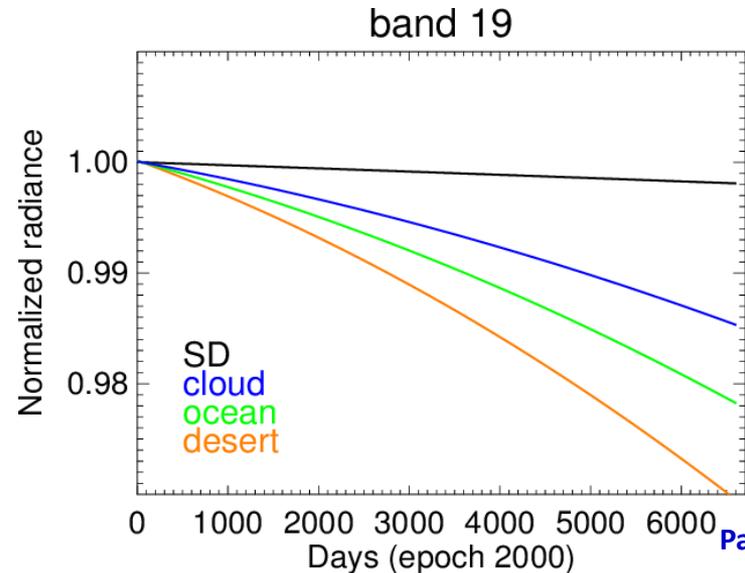
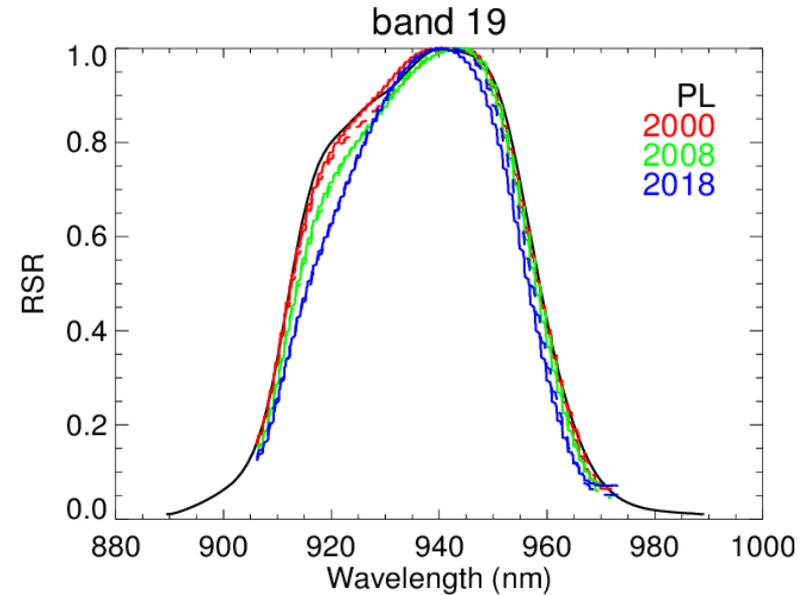
SRCA spectral calibration measures in-band RSR on-orbit

- Aqua – All bands show very little on-orbit change.
- Terra – Most bands show very little on-orbit change. Exceptions are bands 1, 4, 17, **19** →
- Bands 8, 9, 3 not evaluated

Impact of changing RSR on the calibrated radiance is small:

<0.12% for Aqua, <0.4% for Terra.

Impact of changing RSR on Earth scene radiance retrieval may be larger, depending on scene spectrum. Worst case is Terra b19.

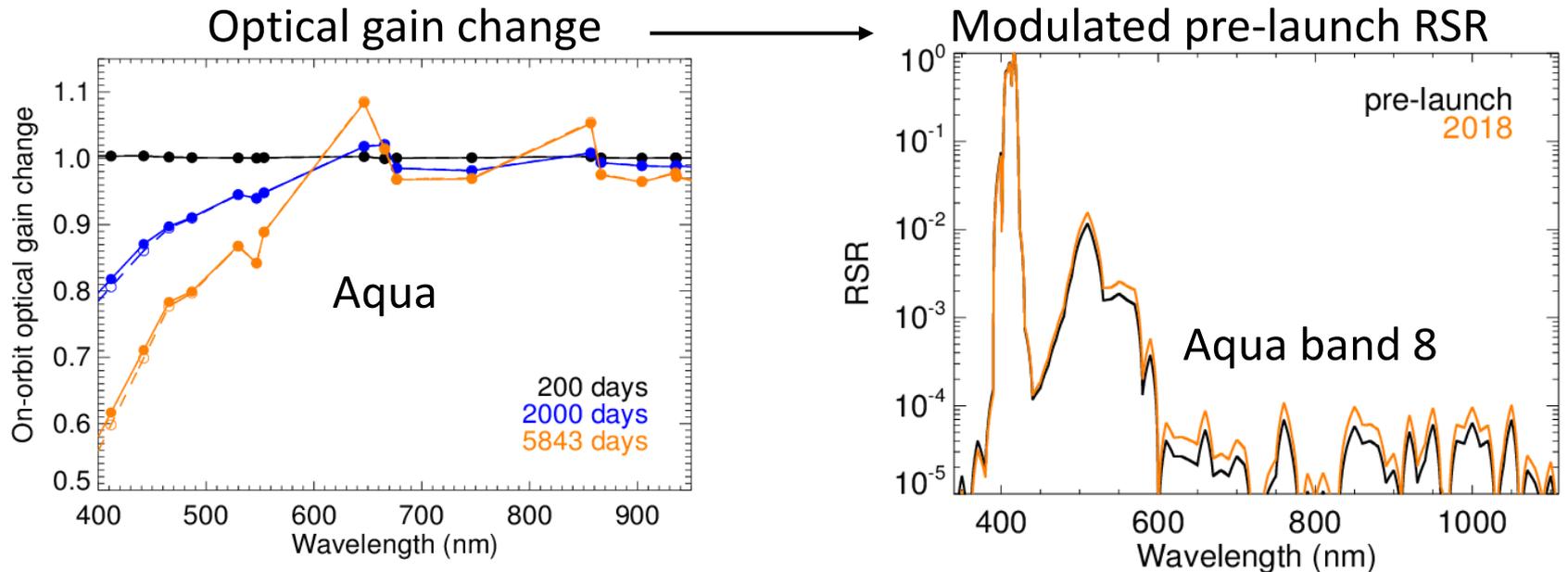




On-orbit RSR changes



Out-of-band portion of RSR changes due to broadband degradation of the instrument optics (mostly scan mirror)



Impact for Aqua – Only band 8 has a significant impact; up to 0.5% at SD AOI, larger at small AOI.

Impact for Terra – Similar, but much higher uncertainty

Changing RSR impact could be included in calibrated L1B in future (similar to NASA VIIRS L1B). But Earth product impact must be considered separately.



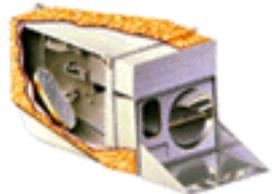
Summary



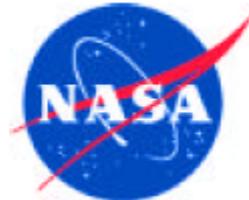
- SD/SDSM and lunar observations are used to track RSB on-orbit gain change
 - Additional information from EV response from desert sites are used for select RSB (Terra 1-4, 8-10 and Aqua 1-4, 8-9)
- Shorter wavelength VIS Bands show larger degradation (strong wavelength, mirror-side, and scan-angle dependence)
 - Gain change over 50% seen in Terra Band 8 (.412 μm) at the AOI of SD (50.25°)
- NIR bands gain change generally within 10%
- SWIR bands gain change within 10%
- Successful recovery from the Terra safe-mode event
 - RSB continue to perform nominally after the safe-mode. Noticeable gain changes ($\sim 2\%$) for the SWIR bands observed after the safe-mode event. VIS/NIR bands show changes $< 1\%$
- Challenges for future calibration:
 - Continued degradation of the solar diffusers and changes in RVS may impact gain accuracy of more bands, forcing more reliance of EV-based calibration
 - Correcting for impacts of polarization
 - Changes to SWIR band OOB/xtalk effects



MODIS TEB Performance



MCST Workshop at MST Meeting (October 18, 2018)





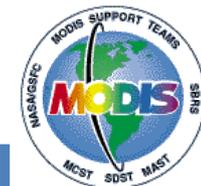
Outline



- MODIS TEB and on-orbit calibration
- TEB calibration performance
 - Blackbody and CFPA temperature trends
 - Detector gain coefficient trends
 - Detector NEdT trends and QA table
 - Uncertainty
- TEB calibration assessment using cold targets
- Summary



TEB Design Specifications



Band	CW	Ttyp	NEdT	UC (%)	UC (K)	Primary Use
20	3.75	300	0.05	0.75	0.18	Surface/cloud temperature
21	3.96	335	0.20	1	0.31	
22	3.96	300	0.07	1	0.25	
23	4.05	300	0.07	1	0.25	
24	4.47	250	0.25	1	0.19	Atmosphere temperature
25	4.52	275	0.25	1	0.24	
27	6.72	240	0.25	1	0.27	Water vapor
28	7.33	250	0.25	1	0.32	
29	8.55	300	0.05	1	0.53	Cloud properties
30	9.73	250	0.25	1	0.42	Ozone
31	11.03	300	0.05	0.5	0.34	Surface/cloud temperature
32	12.02	300	0.05	0.5	0.37	
33	13.34	260	0.25	1	0.62	Cloud top altitude
34	13.64	250	0.25	1	0.59	
35	13.94	240	0.25	1	0.55	
36	14.24	220	0.35	1	0.47	

CW: center wavelength in micron;
Ttyp: typical scene temperature in K;
NEdT: noise equivalent temperature difference in K



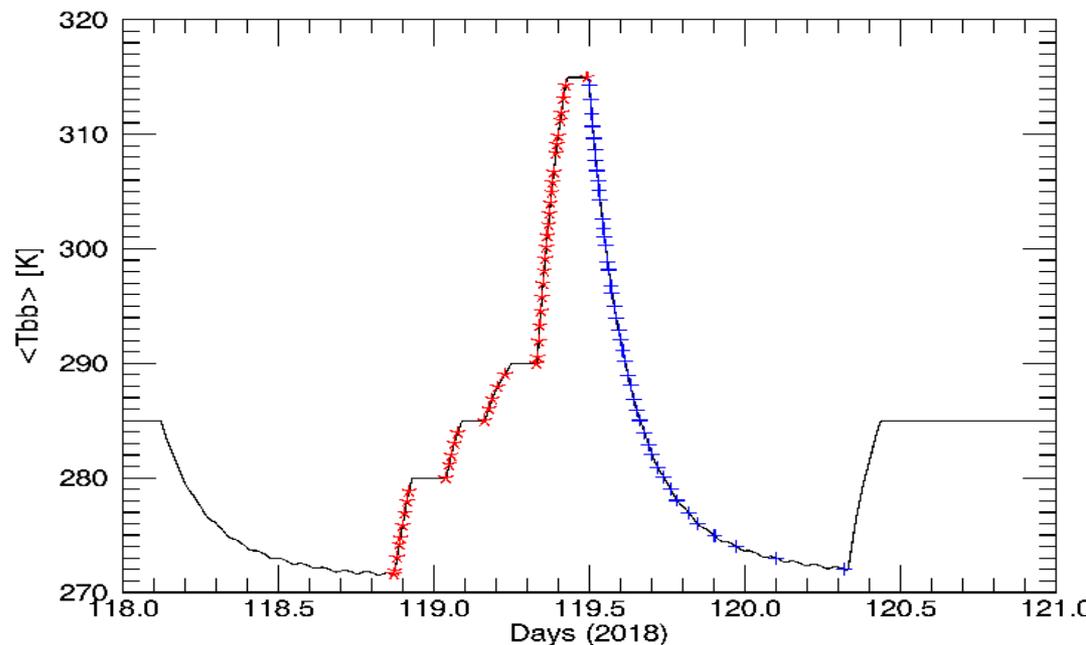
On-orbit Calibration Methodologies



EV Radiance:
$$L_{EV} = \frac{I}{RVS_{EV}} \left(a_0 + b_1 \cdot dn_{EV} + a_2 \cdot dn_{EV}^2 - (RVS_{SV} - RVS_{EV}) \cdot L_{SM} \right)$$

Calibration Coefficients:

$$b_1 = \left(RVS_{BB} \cdot \varepsilon_{BB} \cdot L_{BB} + (RVS_{SV} - RVS_{BB}) \cdot L_{SM} + RVS_{BB} \cdot (1 - \varepsilon_{BB}) \cdot \varepsilon_{cav} \cdot L_{cav} - a_0 - a_2 \cdot dn_{BB}^2 \right) / dn_{BB}$$



- RVS:** response versus scan-angle
- e:** emissivity
- L:** spectral band integrated radiance
- dn:** digital count with background corrected
- a0 & a2:** non-linear gain coefficients
- b1:** linear gain coefficient

WUCD T_{BB} : ~270 K to 315 K



On-orbit Calibration Methodologies



- **Regular BB Calibration**
 - Compute linear gain coefficient b_1 on a scan-by-scan basis; 40-scan running average used in the L1B product
- **Quarterly BB Warm-up and Cool-down (WUCD) Activities**
 - Compute nonlinear gain coefficients a_0 and a_2
 - Derive fixed linear coefficients for band 21
- **Special Calibration Issues**
 - Characterization of response versus scan angle
 - Aqua CFPA temperature fluctuation
 - Aqua default b_1 and EV image saturation for bands 33, 35 and 36
 - Terra PC (bands 32-36) and PV (bands 27-30) crosstalk
 - Uncertainty
- **Independent calibration stability monitoring**
 - EV scene (Dome-C, Ocean, DCC)
 - Measurement in scheduled lunar events
 - Inter-comparisons



MODIS Collection 6.1



Band	Aqua			Terra					
	Calibration algorithm	CFPA temperature	Default b_1	Calibration algorithm	Cross-talk correction				
20	PL a_0 PL adjusted CD a_2	CFPA temperature correction applied in the fitting		$a_{0_ms1} = 0$ $a_{0_ms2} = a_{0_ms2}^{free-fit} - a_{0_ms1}^{free-fit}$ CD a_2	PV electronic cross-talk				
22									
23									
24									
25									
27									
28									
29									
30									
31	$a_0=0$, CD a_2			$a_0 = 0$ CD a_2	PC optical cross-talk				
32									
33	$a_0=0$ PL adjusted CD a_2						Applied	$a_0 = 0$ CD a_2	PC optical cross-talk
34									
35									
36									
								Applied	

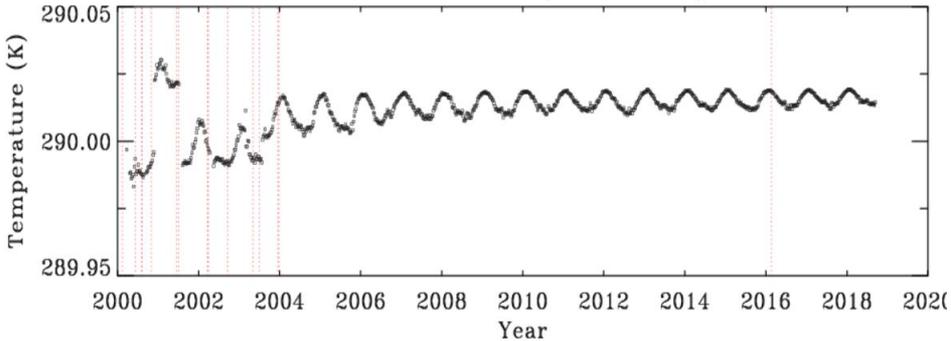
- Band 21: Linear calibration using CD data.



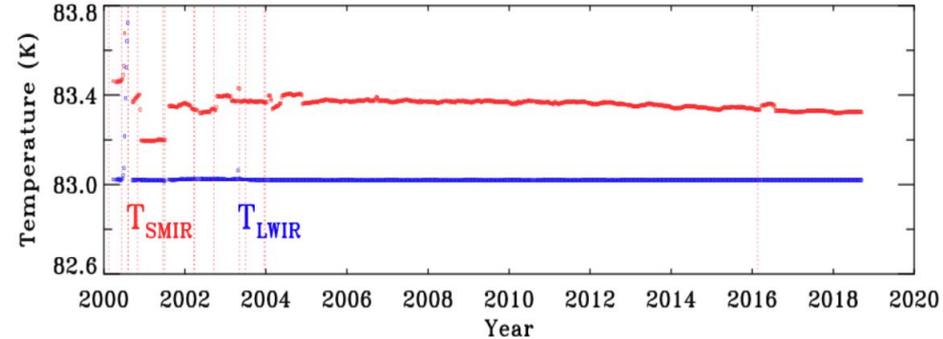
Key Telemetry Temperatures



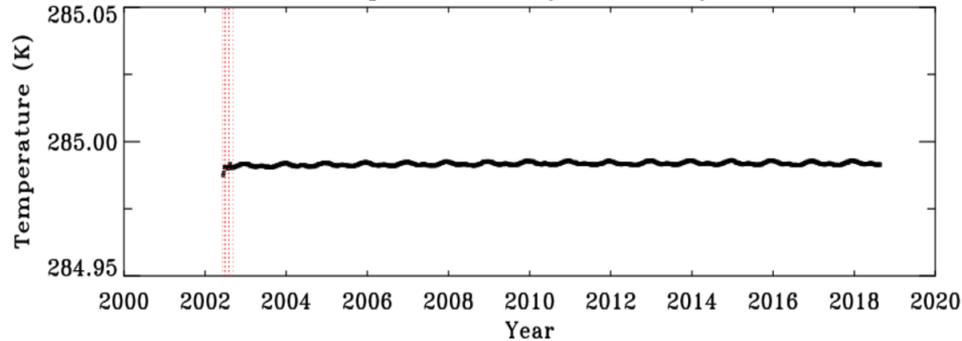
Terra Blackbody Telemetry



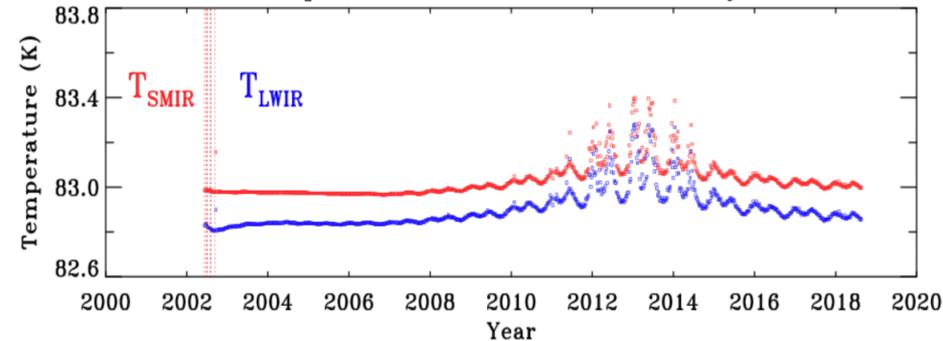
Terra SMIR & LWIR FPA Telemetry



Aqua Blackbody Telemetry



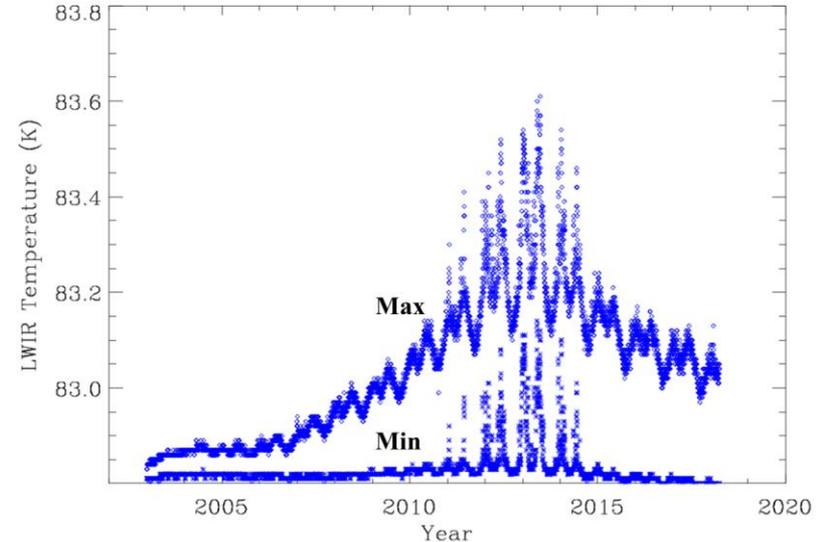
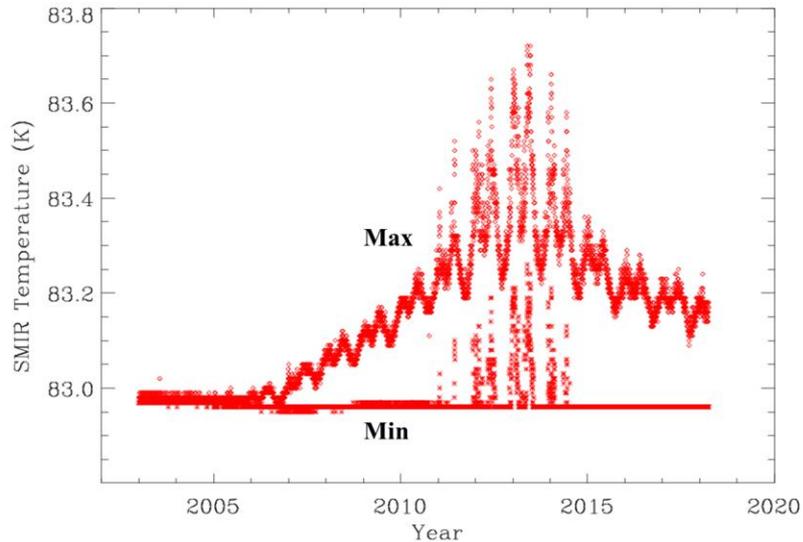
Aqua SMIR & LWIR FPA Telemetry



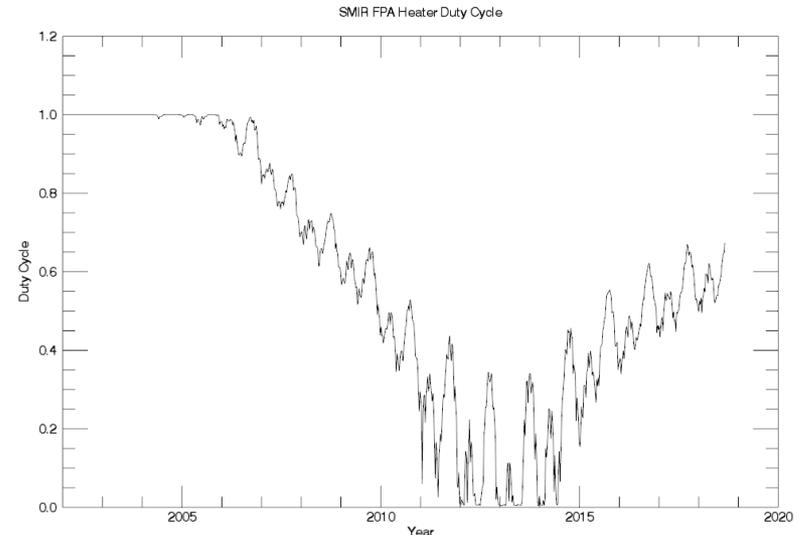
- Terra BB temperature 290K, ~10mK fluctuation
- Aqua BB temperature 285K, stable
- Terra LWIR CFPA actively controlled (83K), both stable
- Aqua SMIR CFPA actively controlled (83K), detail next page



Aqua CFPA temperature



- Mitigation since 2013
 - Increase of radiative cooler margin
 - Improvement of temperature control
 - Reduction of EV saturation (bands 33, 35 & 36) instance during WUCD.
- Scan-by-scan calibration captures much of the impact of the CFPA variation
- Improved default b1 algorithm implemented
- Temperature correction to the a0/a2 analysis implemented

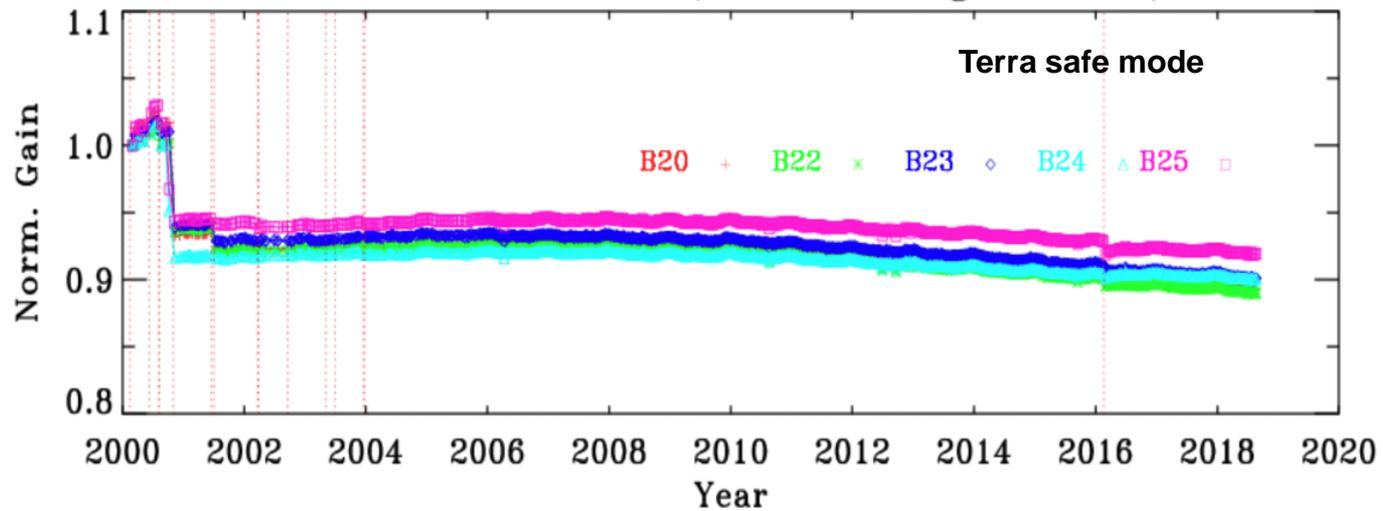




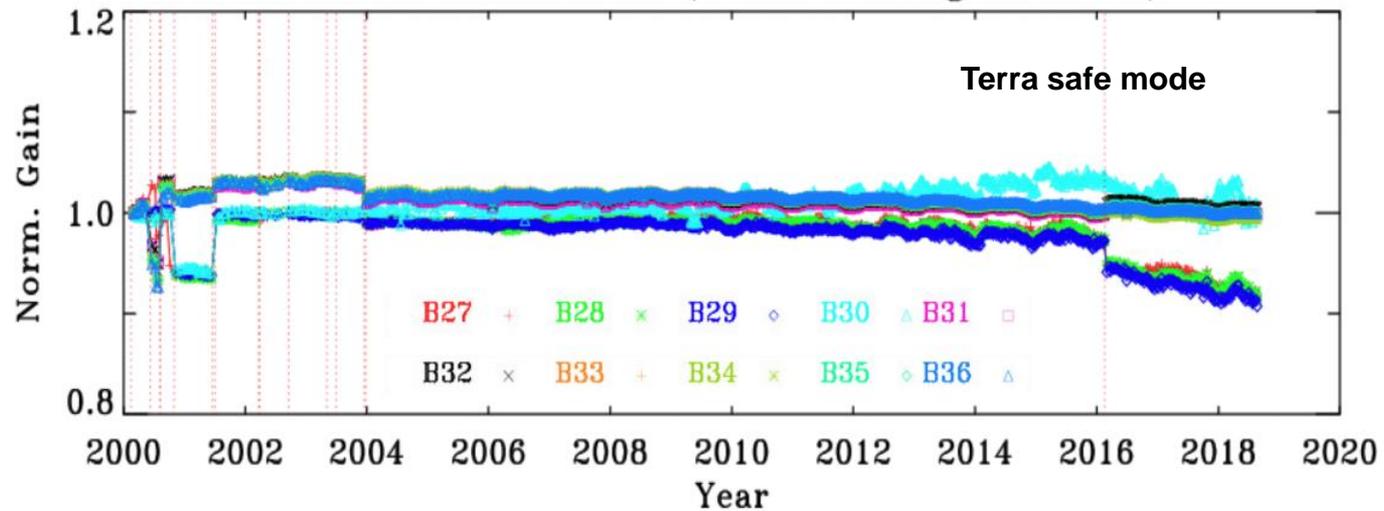
Terra TEB Gain Trending



Terra MODIS MWIR (Band-Averaged, MS 1)



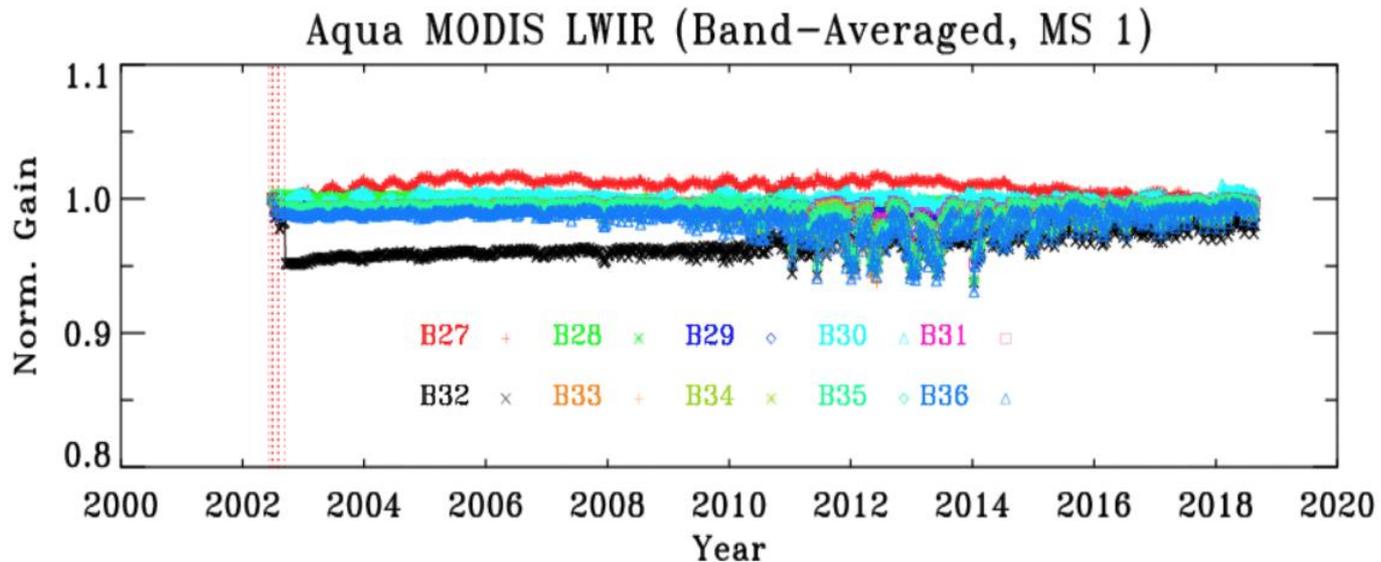
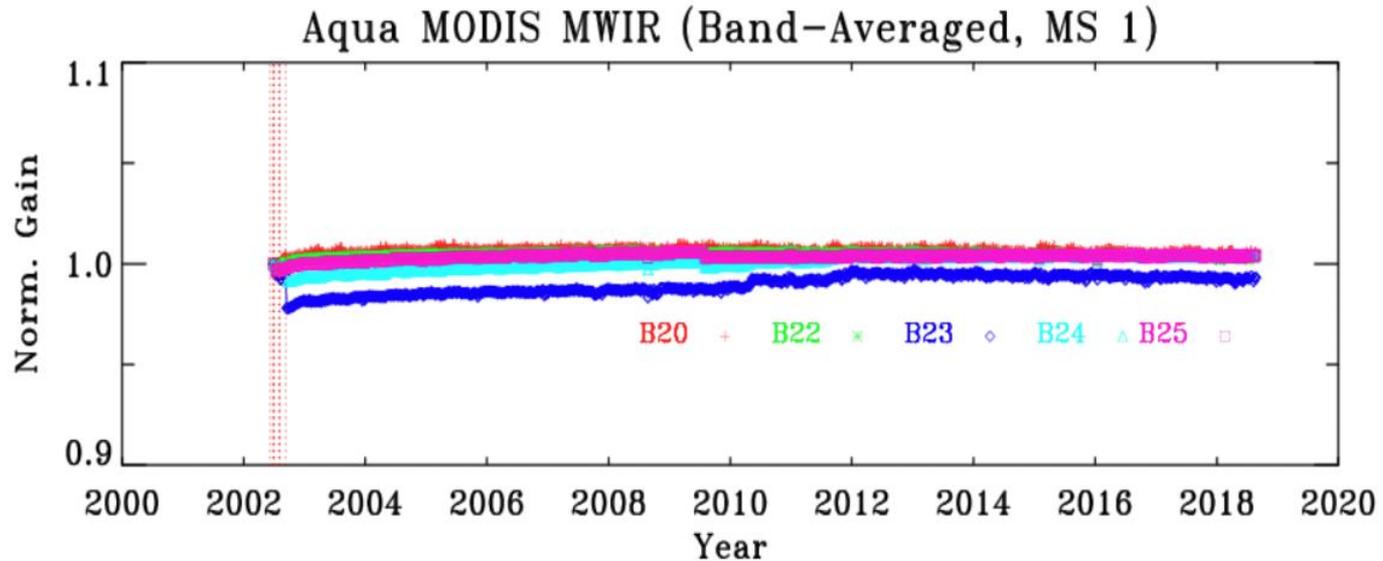
Terra MODIS LWIR (Band-Averaged, MS 1)



➤ Safe model causes gain changes for some bands



Aqua TEB Gain Trending



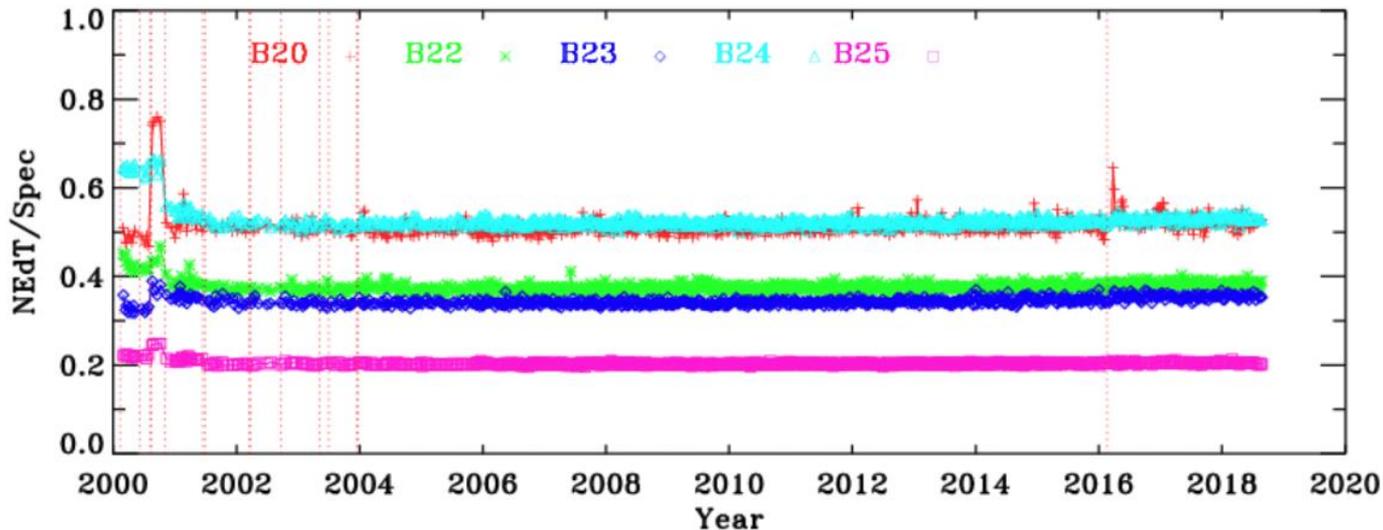
➤ CFPA temperature impacts on gain for LWIR bands



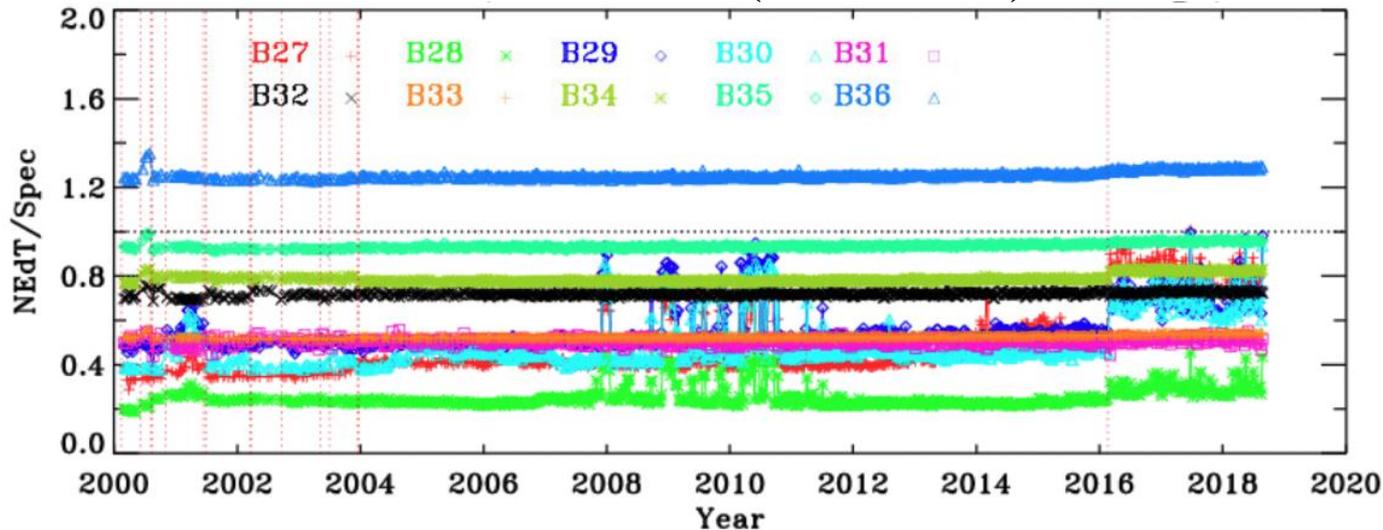
Terra TEB Noise Trending



Terra MODIS MWIR (bands 20-25) MS1



Terra MODIS LWIR (bands 27-36) MS1



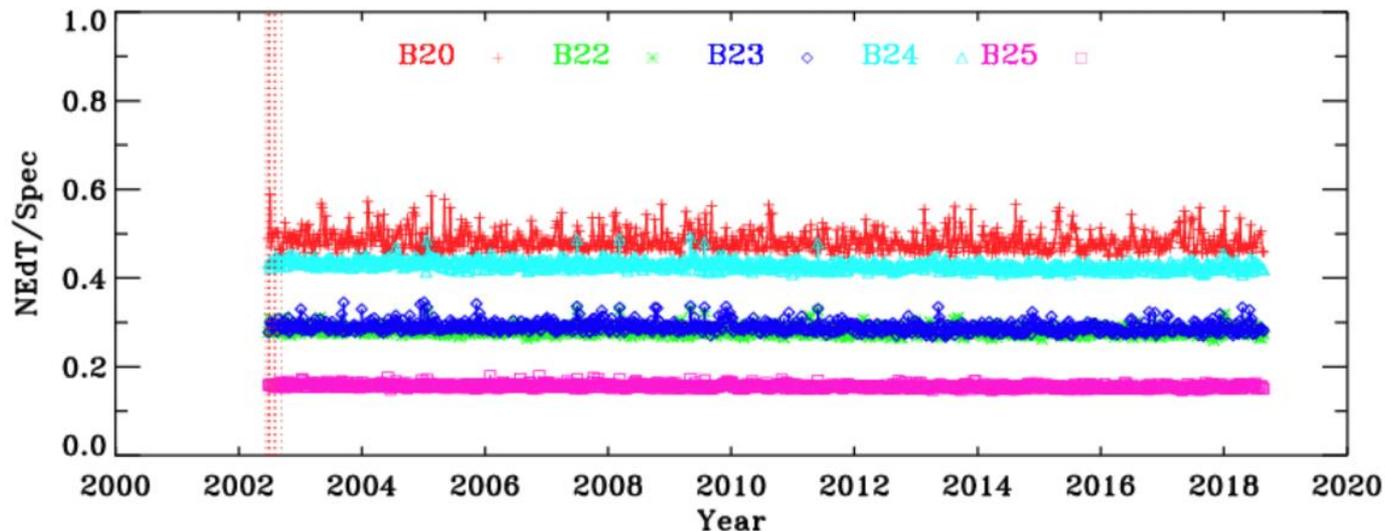
- Safe model causes NEdT jumps for PV LWIR bands
- Band 30 all detectors are noisy



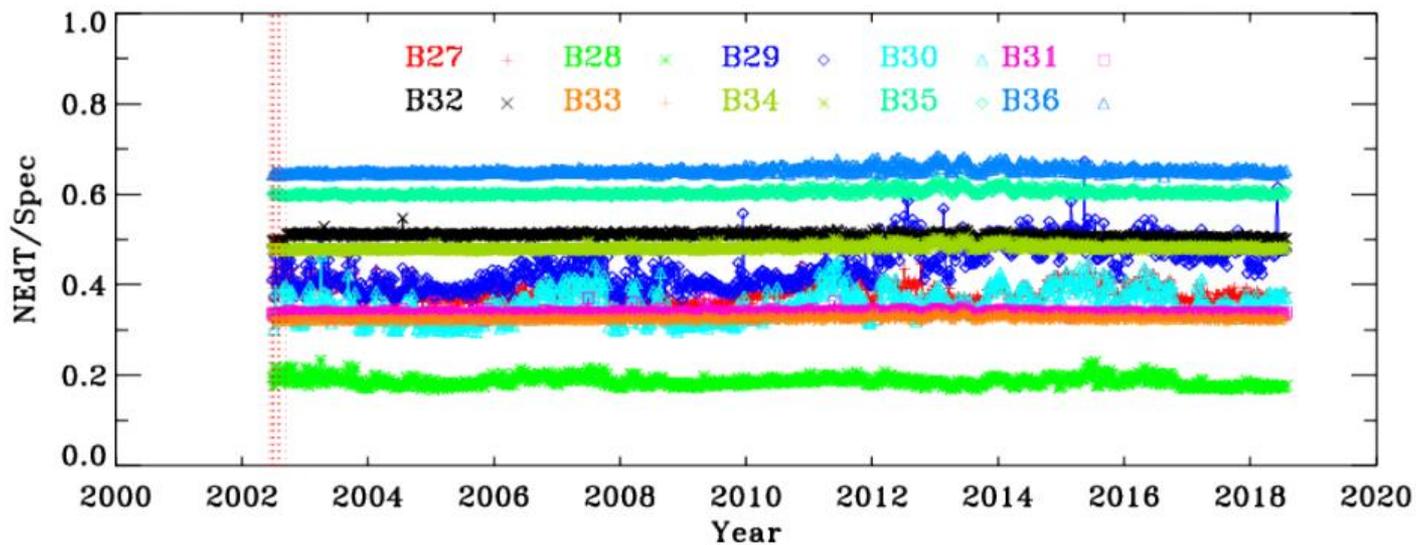
Aqua TEB Noise Trending



Aqua MODIS MWIR (bands 20-25) MS1



Aqua MODIS LWIR (bands 27-36) MS1





Collection 6.1 TEB QA Table



Terra

Aqua

BD	1	2	3	4	5	6	7	8	9	10
20	Green									
21	Green									
22	Green									
23	Green									
24	Green									
25	Green									
27	Yellow	Green	Yellow	Yellow						
28	Green									
29	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green
30	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green
31	Green									
32	Green									
33	Yellow	Green								
34	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow	Green	Green
35	Green									
36	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Yellow

BD	1	2	3	4	5	6	7	8	9	10
20	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
21	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Yellow	Green
22	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
23	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
24	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
25	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
27	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green
28	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
29	Green	Yellow	Green	Green	Green	Yellow	Green	Yellow	Green	Green
30	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
31	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
32	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
33	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
34	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
35	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
36	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green

- Current QA table
- Product order

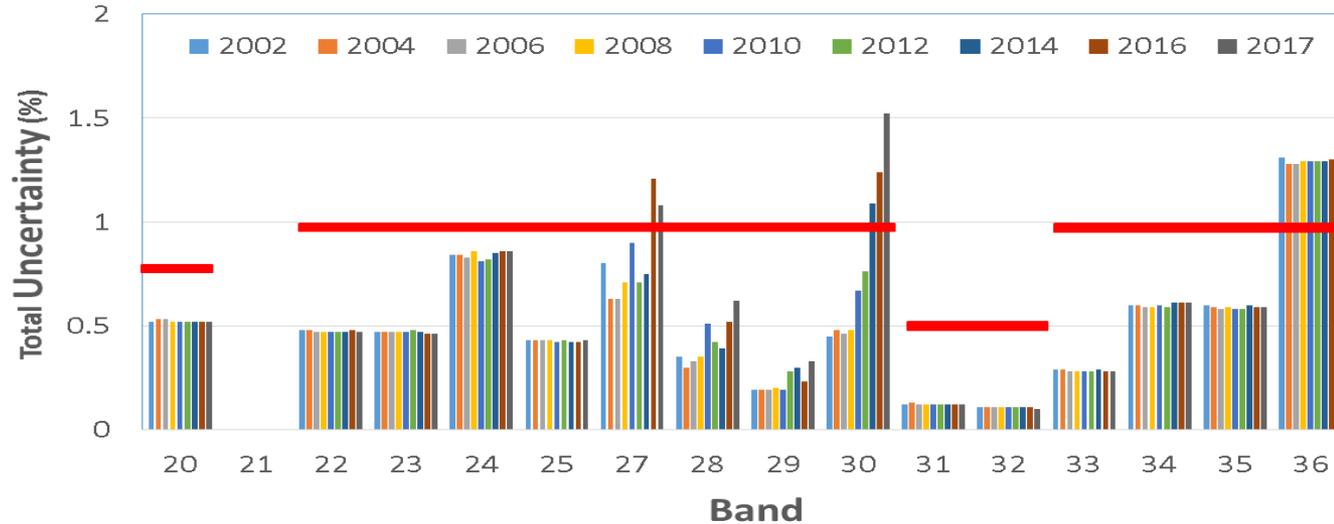
noisy
 inoperable



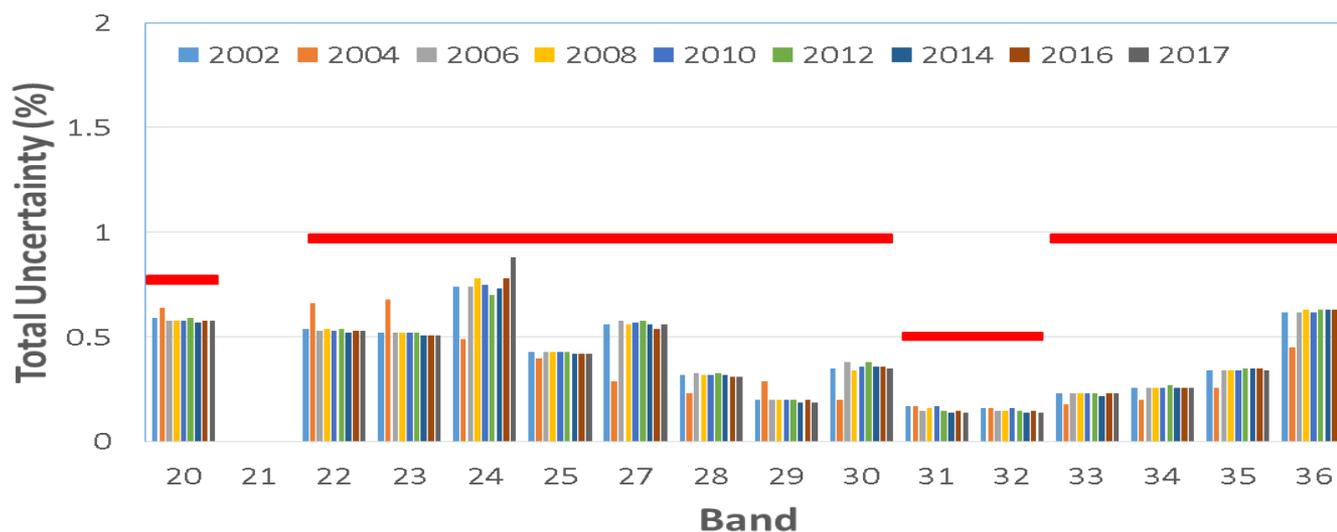
TEB Yearly Uncertainty Trend



Terra Total Uncertainty at Typical Radiance (Nadir, C6.1)



Aqua TEB Uncertainty at Typical Radiance (Nadir, C6.1)



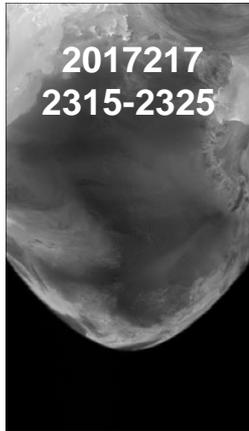
- Terra bands 27 and 30 uncertainty are higher than spec in recent years due to cross-talk
- Terra band 30 all detectors are noisy



Terra TEB RVS from pitch maneuver (2017217)



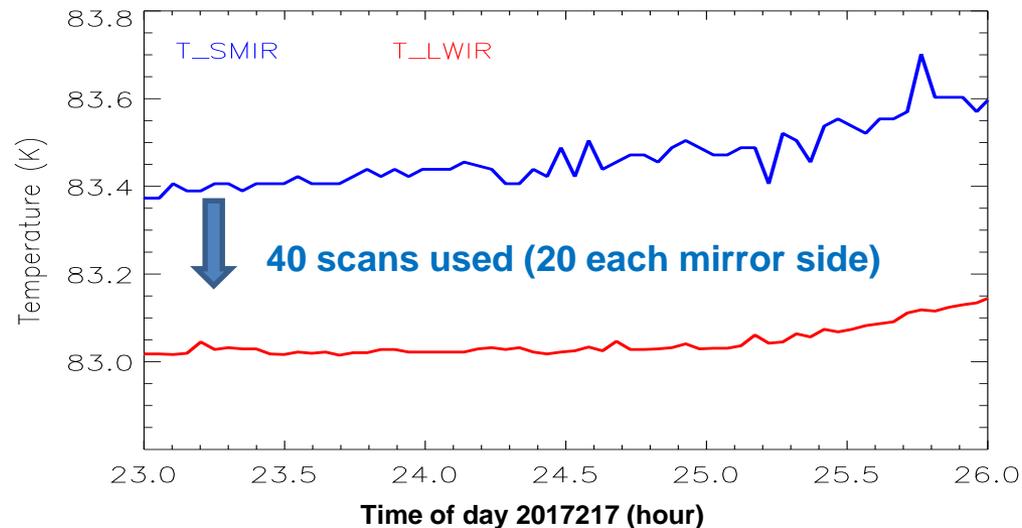
Track



RVS is derived based on detector response to scan mirror's thermal emission (in case of pitch, $L_{EV} = 0$), which is a function of AOI.

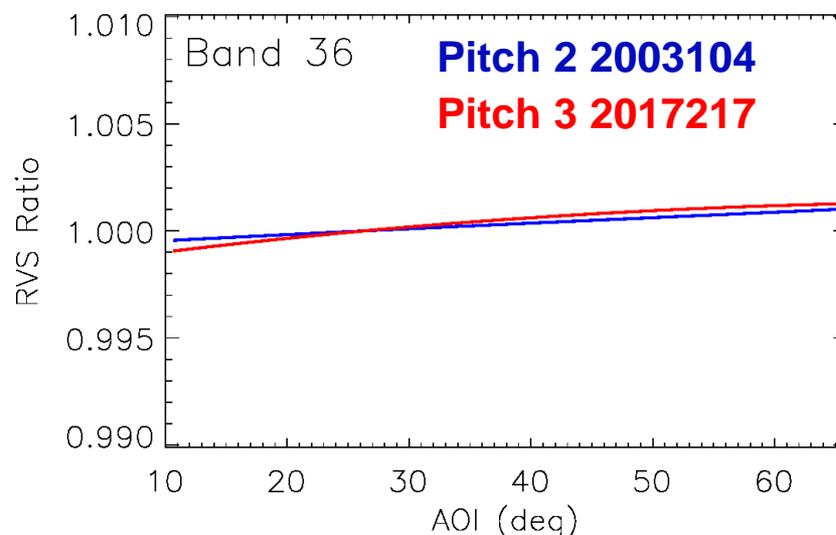
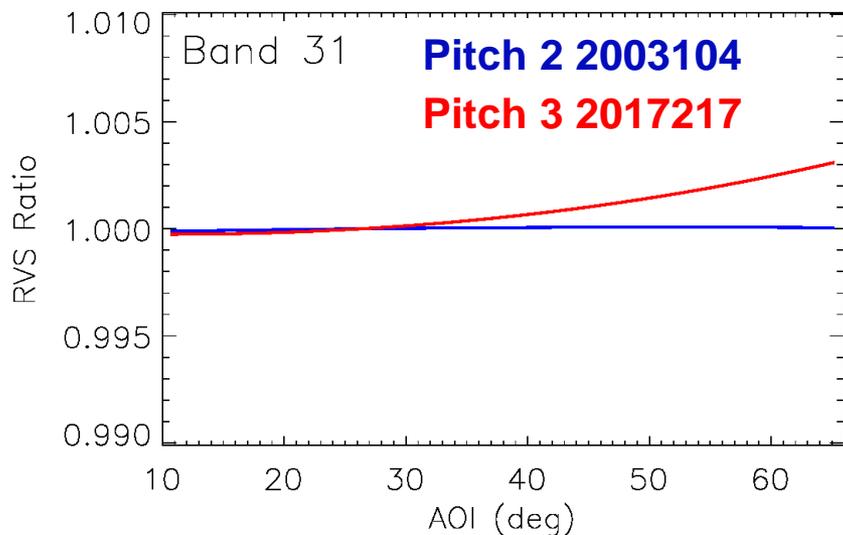
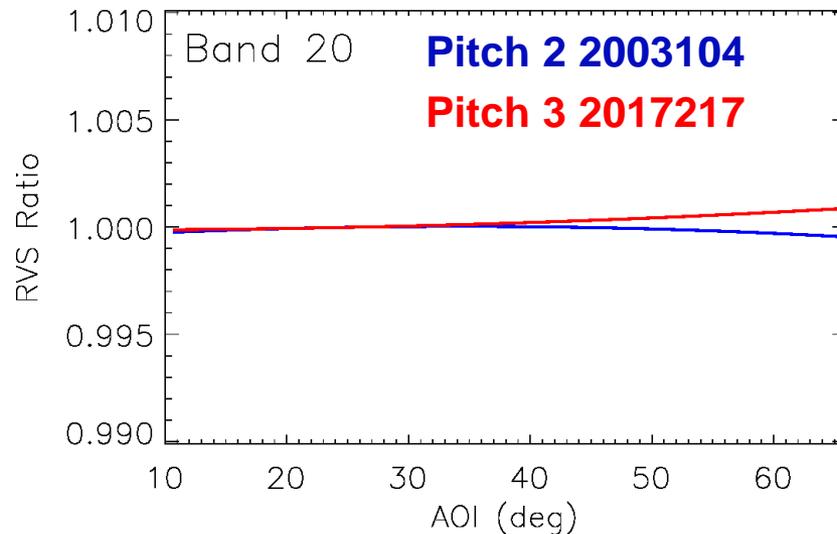
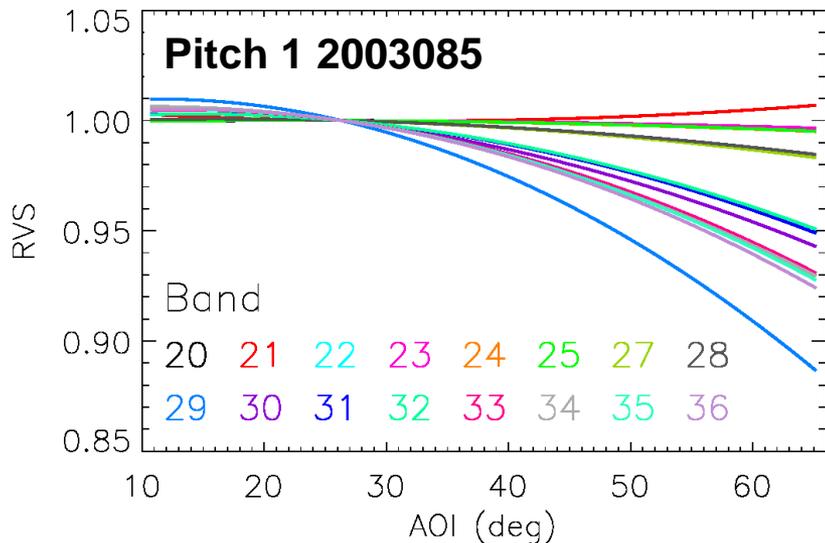
$$RVS_{EV} = 1 - \frac{L_{BB}}{L_{SM}} \frac{(dn_{EV} - dn_{EV=BB})}{(dn_{BB} - dn_{EV=BB})}$$

L_{EV} is the EV radiance, L_{BB} and L_{SM} are the radiances from the blackbody and scan mirror, respectively.





Terra TEB RVS Verification



➤ **2017217 pitch maneuver shows stable RVS (Maximum change is 0.3% for band 31 at large AOI)**



Performance summary



- **Terra MODIS**

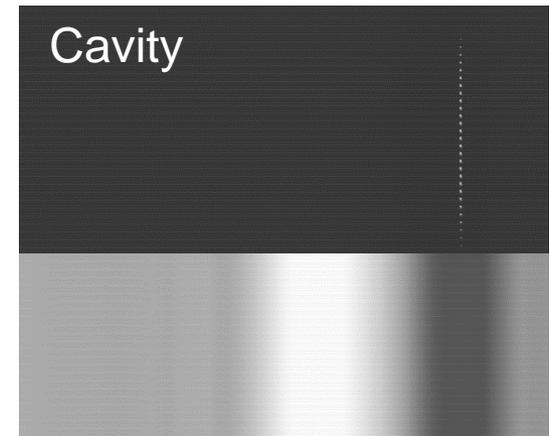
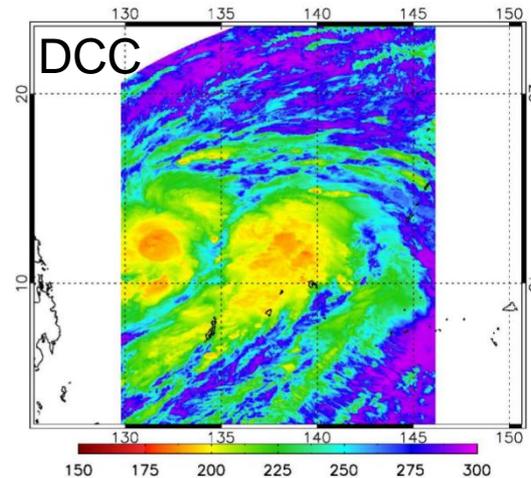
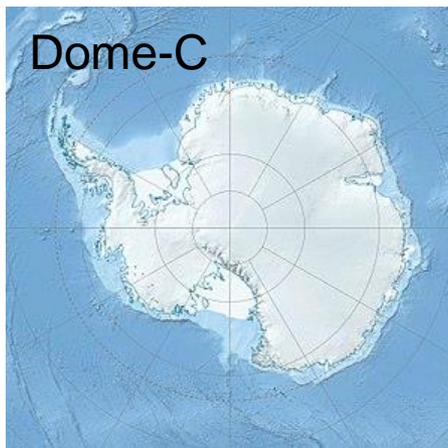
- Overall performance is stable.
- NEdT and uncertainty meet specifications, except band 36 NEdT and uncertainty of bands 27, 30, and 36.
- PV LWIR bands 27-30 electronic cross-talk has been corrected for calibration and EV measurement for Collection 6.1.
- Safe mode in Feb 2016 has some impacts on TEB gain and NEdT, especially for bands 27-30.
- a0/a2 delivery procedure improved to catch the response changes.
- 2017217 pitch maneuver shows stable RVS (Maximum change is 0.3% for band 31 at large AOI)

- **Aqua MODIS**

- Overall performance is stable.
- NEdT and uncertainty meet specifications.
- CFPA temperature mitigated since 2013.



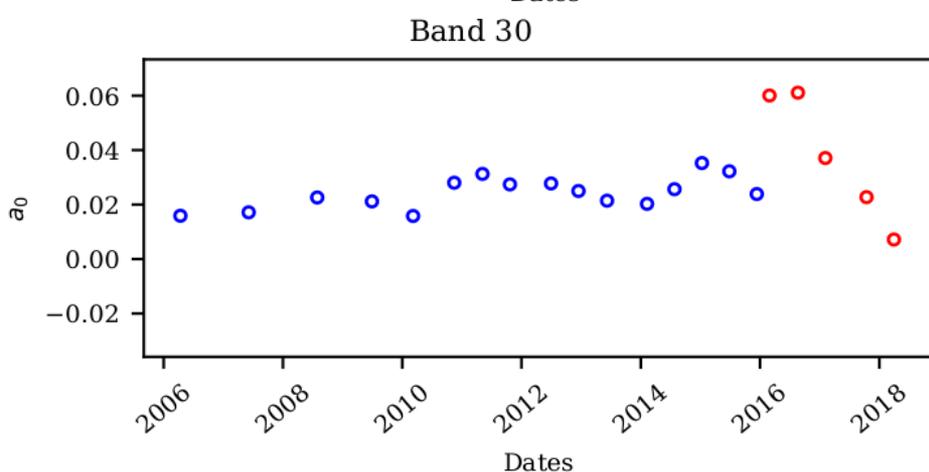
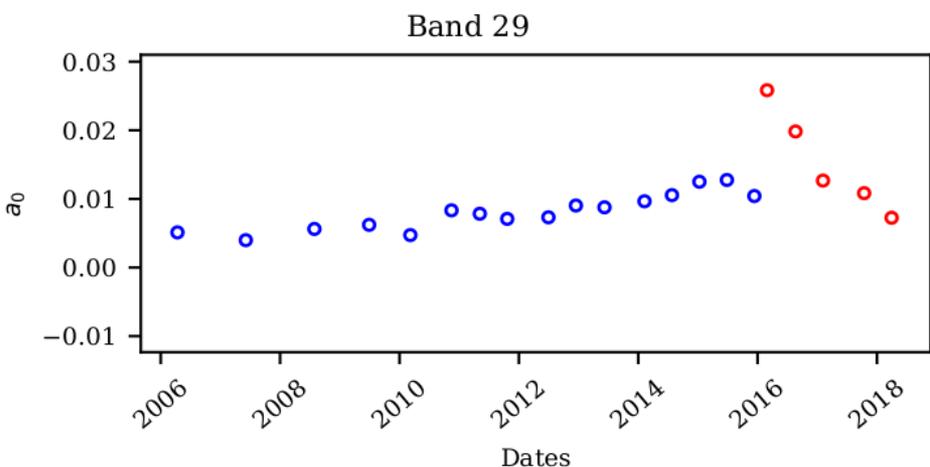
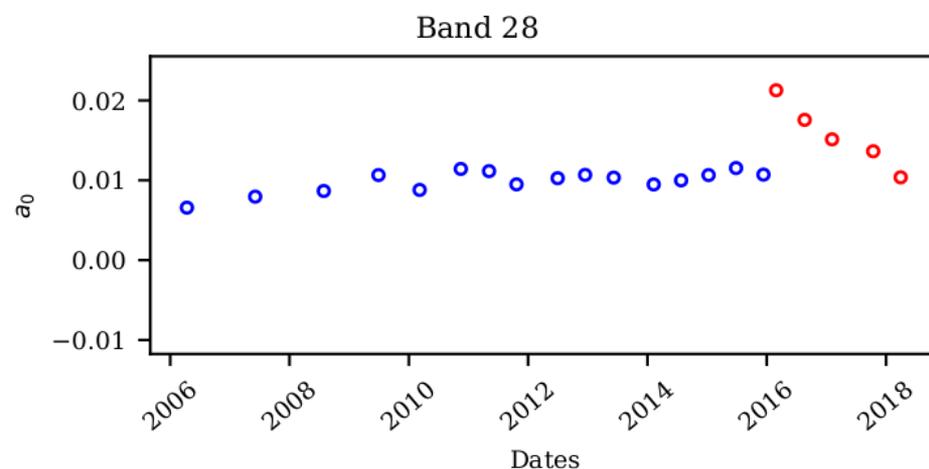
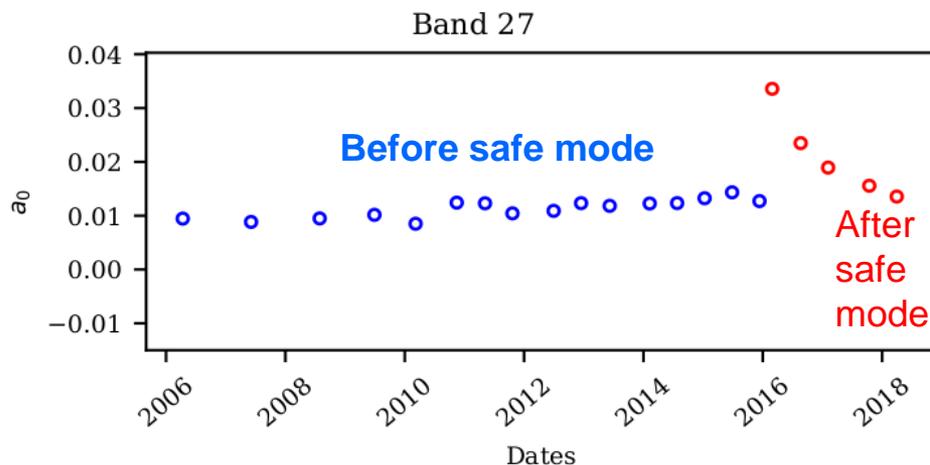
Assessment of Terra MODIS TEB calibration using cold targets and measurements in lunar roll



Reference: T. Chang; X. Xiong; A. Shrestha; A. Wu; N. Chen; Y. Li; Q. Mu “Assessment of Terra MODIS thermal emissive band calibration using cold targets and measurements in lunar roll events” SPIE 10785, Sensors, Systems, and Next-Generation Satellites XXII, 107851C (25 September 2018); doi: 10.1117/12.2325378



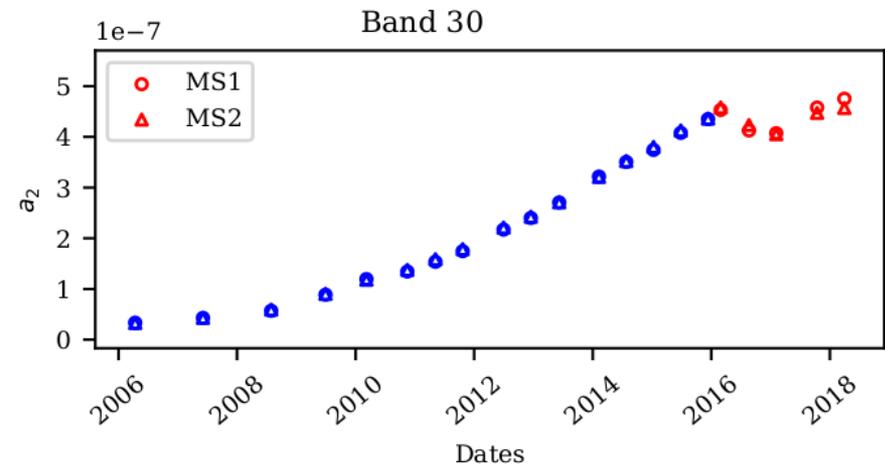
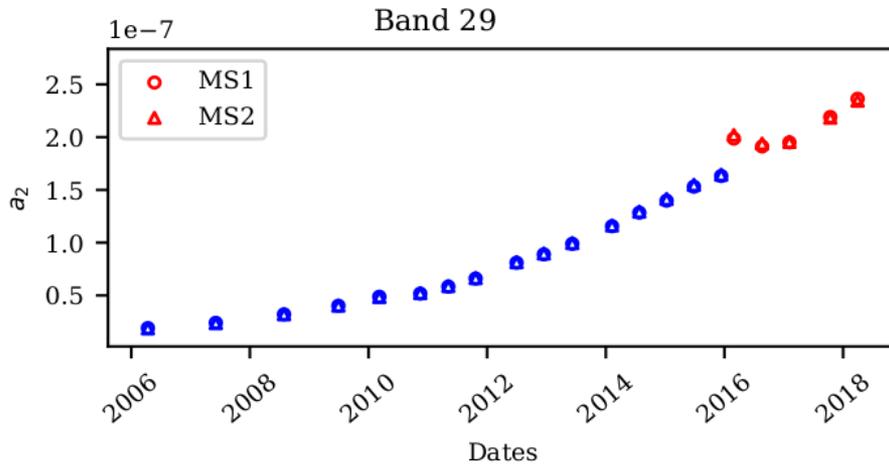
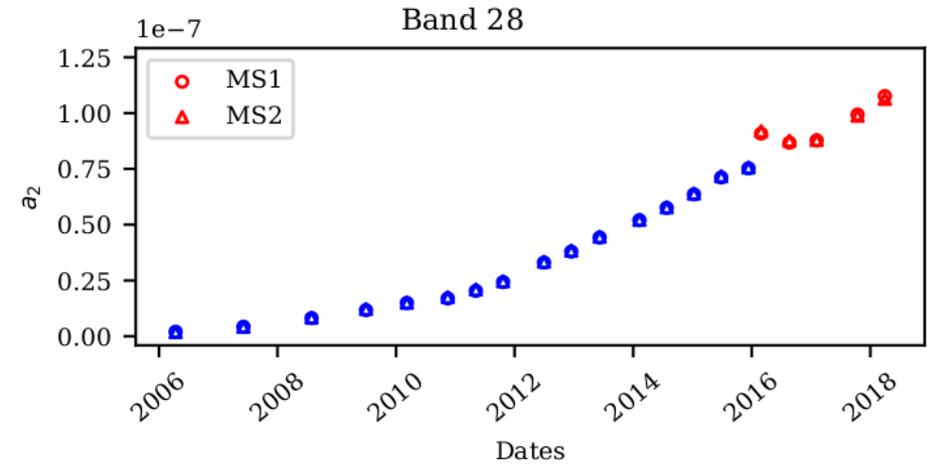
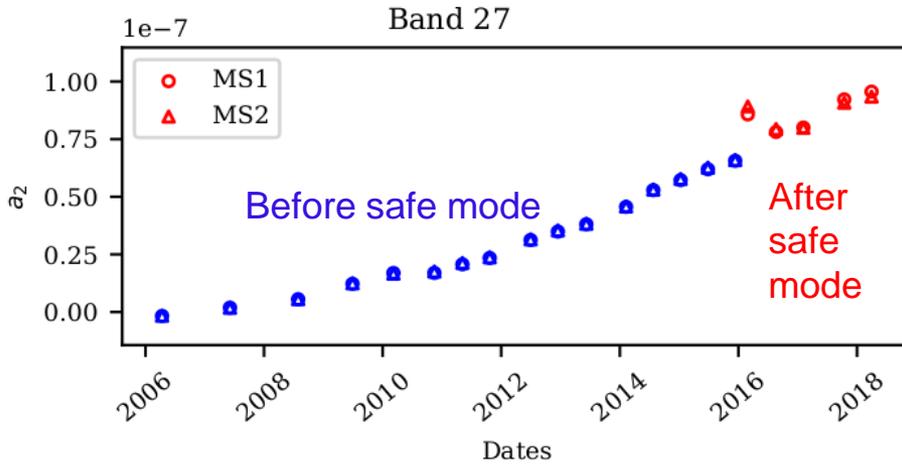
PV LWIR bands calibration coefficient



- $a_{0_msl} = 0$, mirror side two a_0 jumps after safe mode (due to 4 time moving averaging not applied)
- The current LUT coefficients are back to pre-safe mode level
- Low BT scene measurements are sensitive to a_0
- Calibration consistency of mirror sides can be assessed using low BT measurement



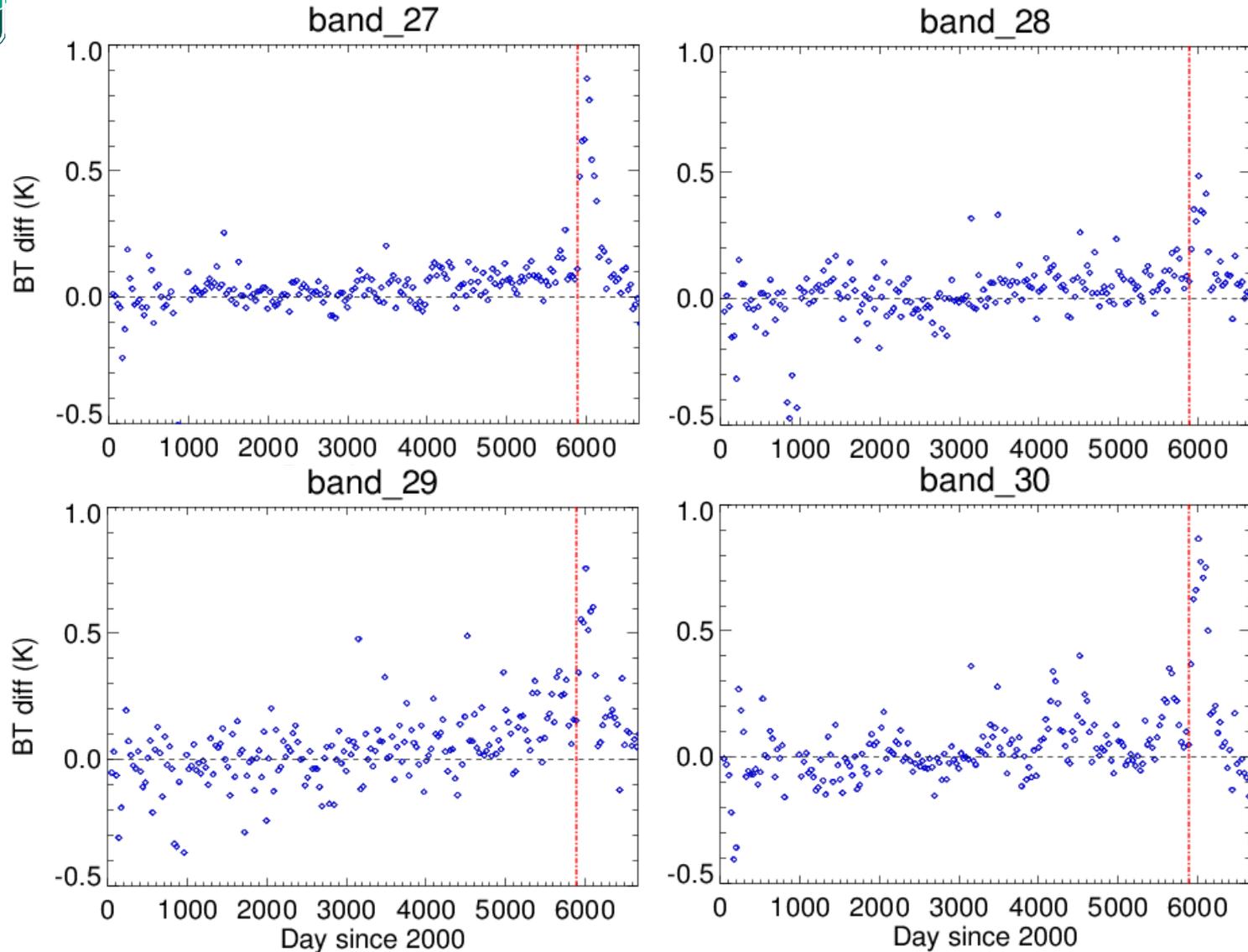
PV LWIR bands calibration coefficient



- The two mirror side are consistent
- a_2 is out of trend after safe mode.
- The current LUT coefficients are back to pre-safe mode level
- Band 30 has slight different pattern after safe mode.



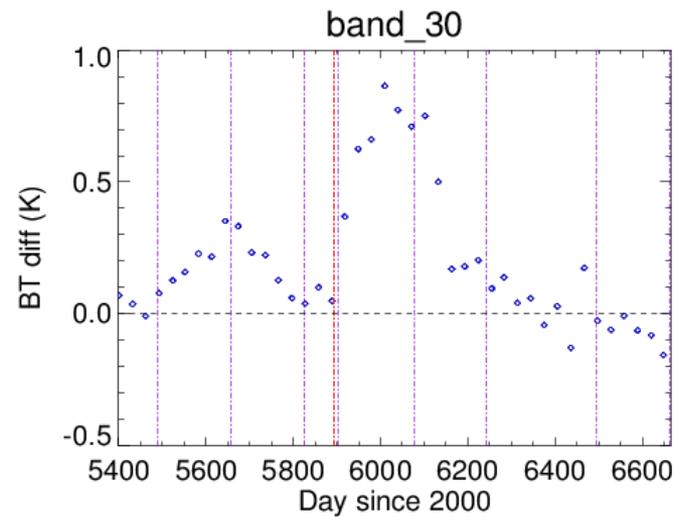
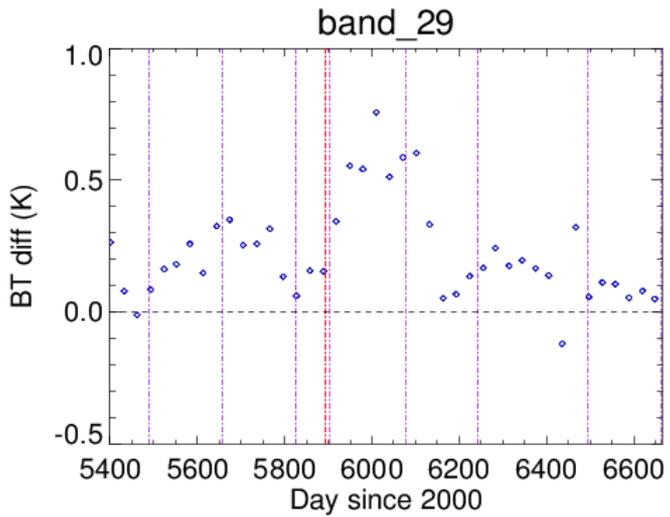
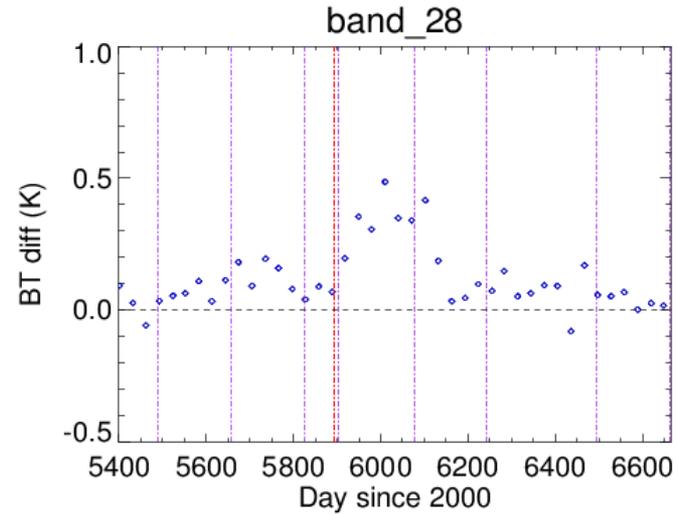
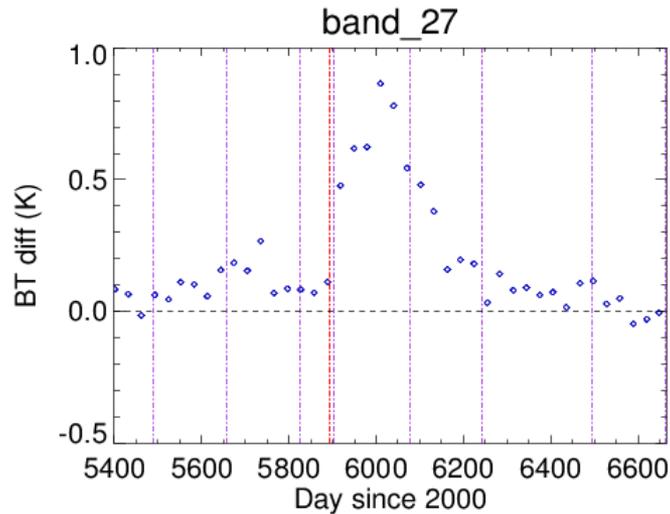
Mirror side difference using Dome-C



- $a_{0_ms1} = 0$, mirror side two a_0 jumps after safe mode
- The mirror side difference jumps after safe mode for these bands



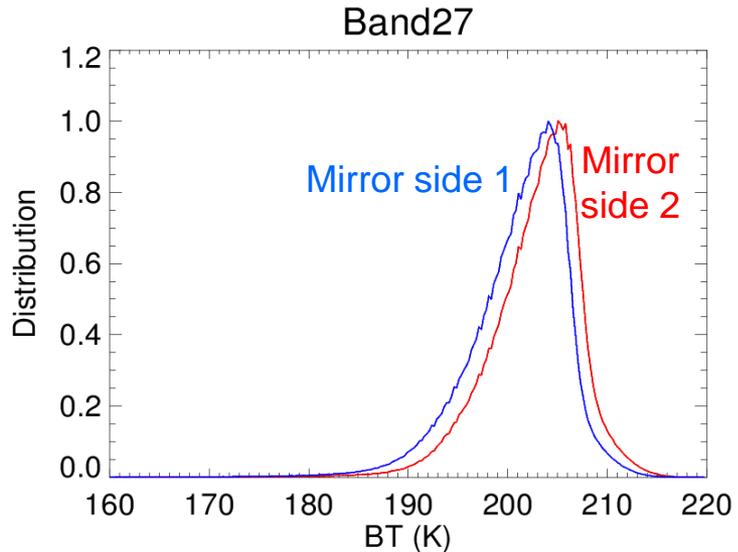
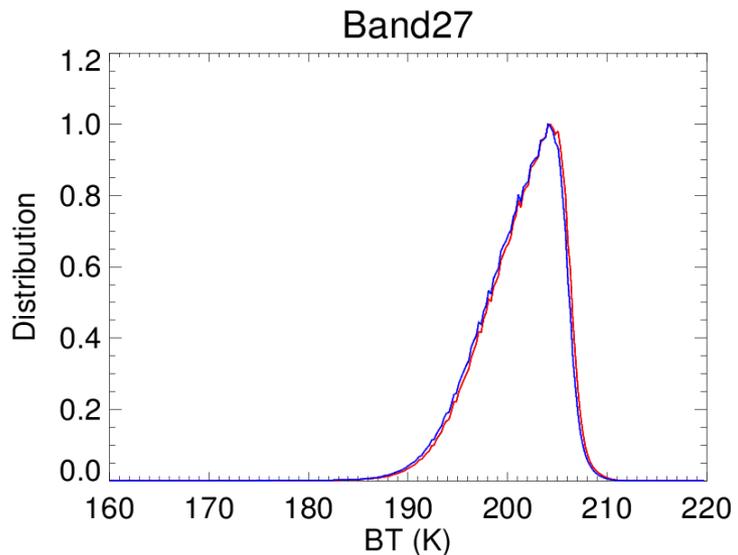
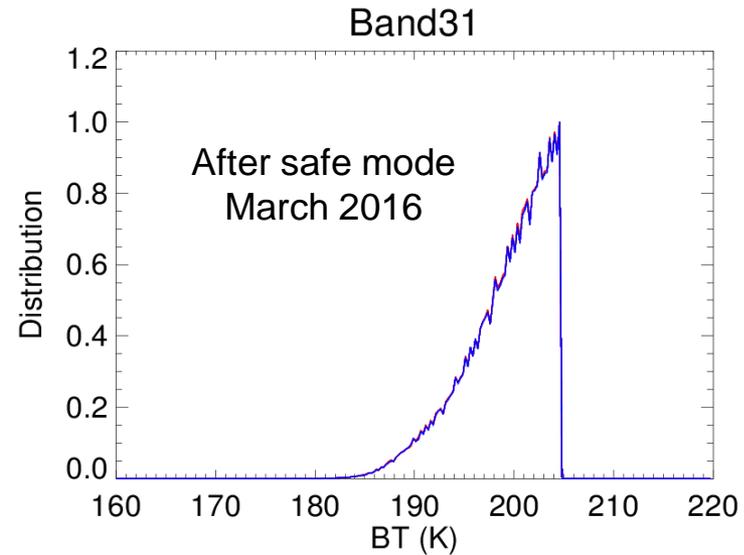
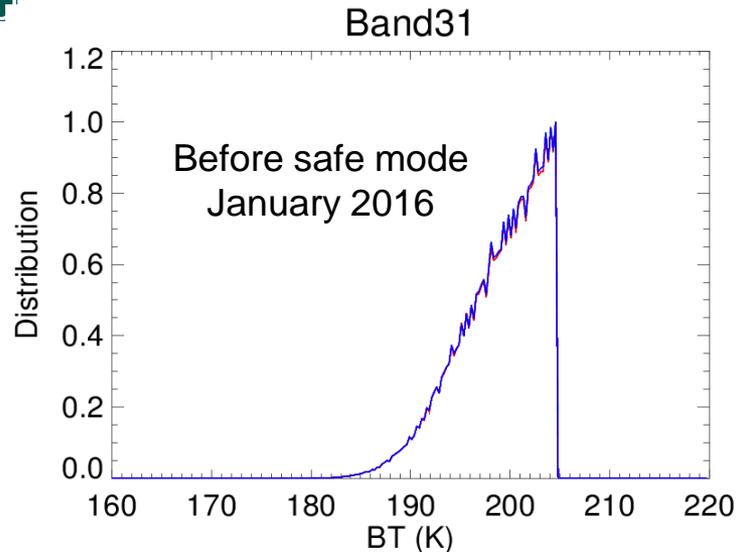
Mirror side difference using Dome-C



- $a_{0_ms1} = 0$, mirror side two a_0 jumps after safe mode
- The mirror side difference jumps after safe mode for these bands



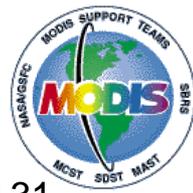
Mirror side difference using DCC



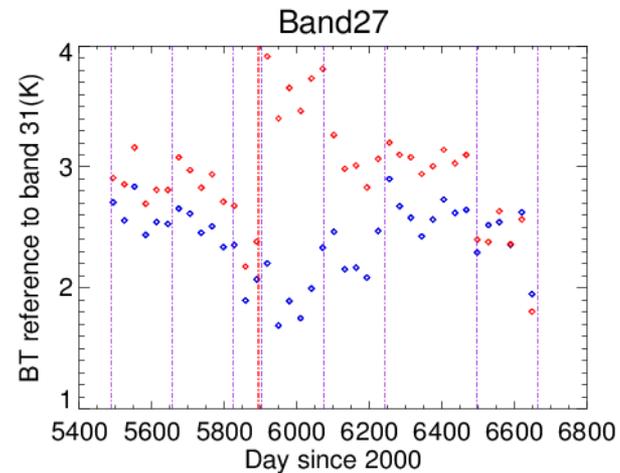
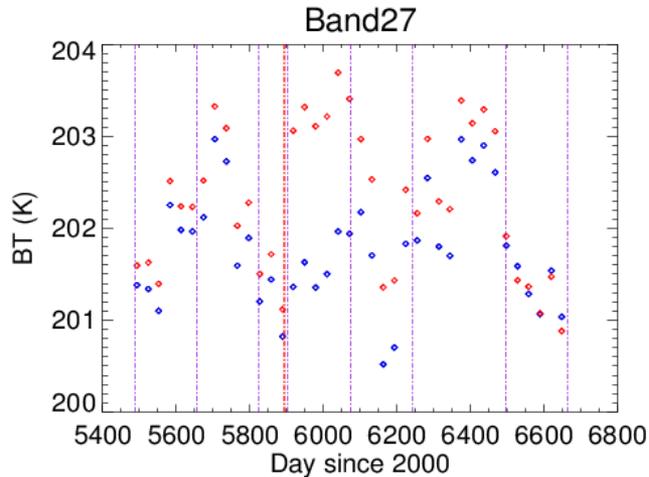
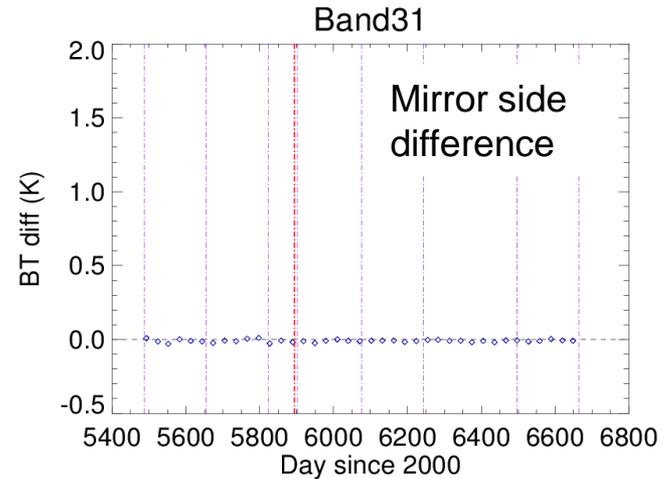
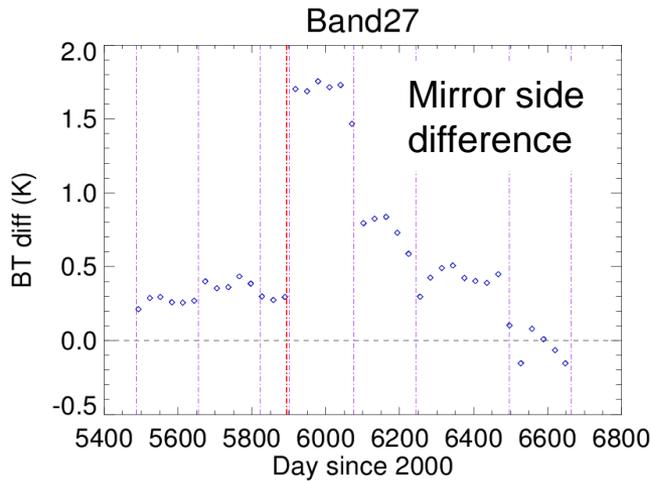
- **Band 31 mirror side difference is stable**
- **Band 27 mirror side difference changes after safe mode**



Mirror side difference using DCC



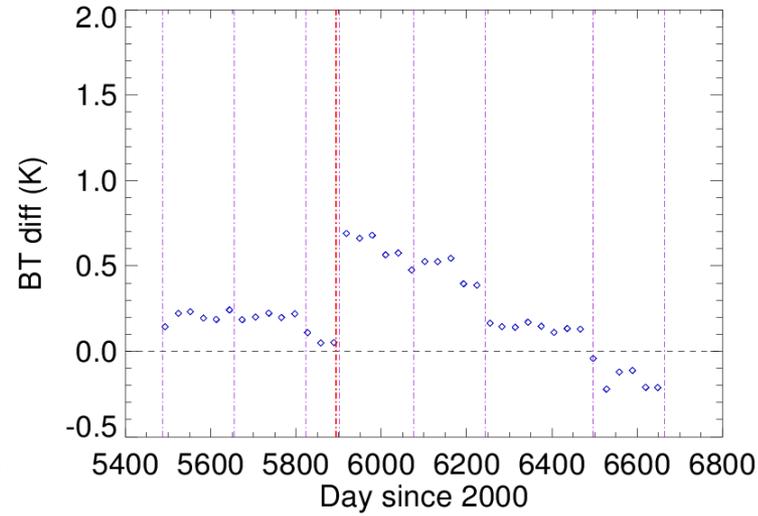
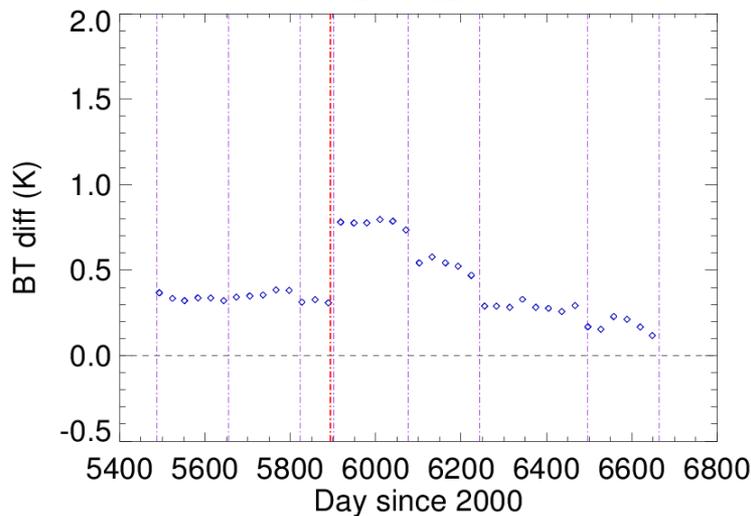
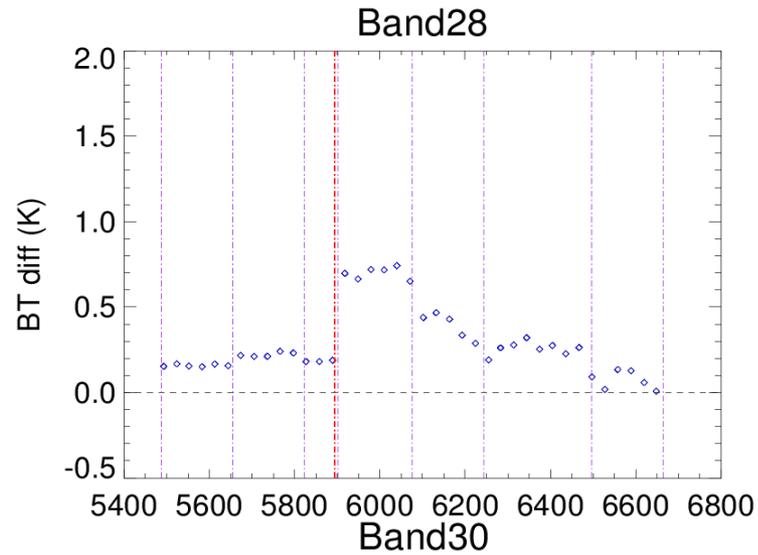
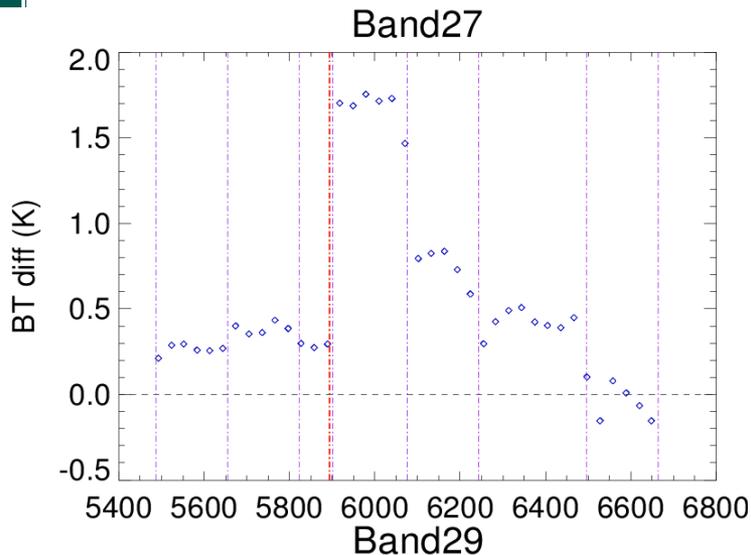
Mirror side difference jumps due to safe mode for band 27. No significant change for Band 31 (Red vertical dash line marks the time of safe mode, purple lines are the LUT update time)



Blue: Mirror side 1 Red: Mirror side 2



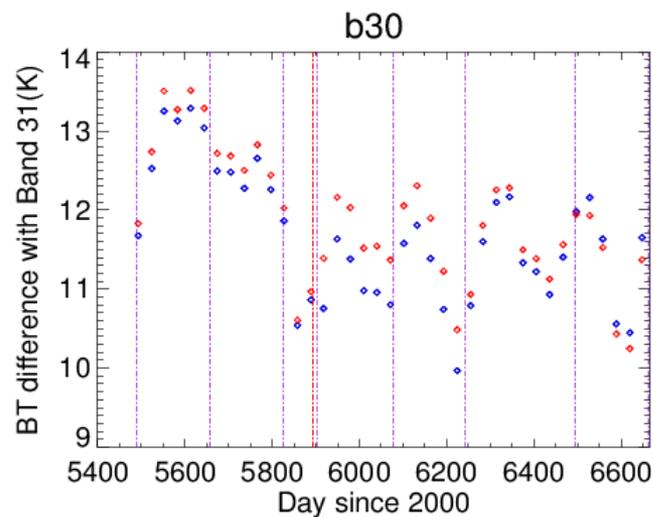
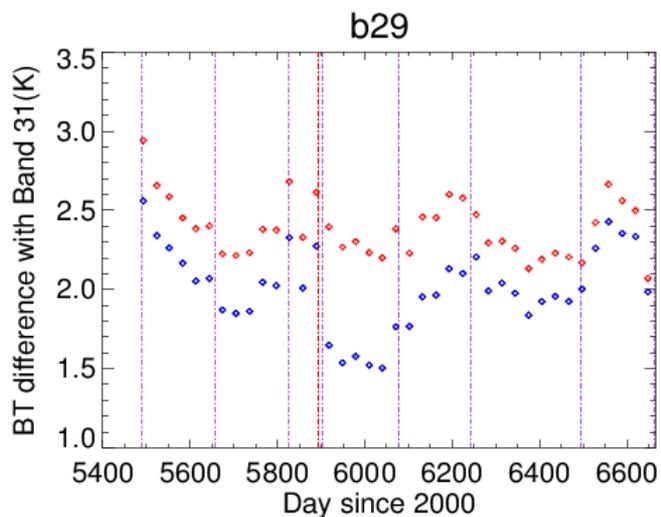
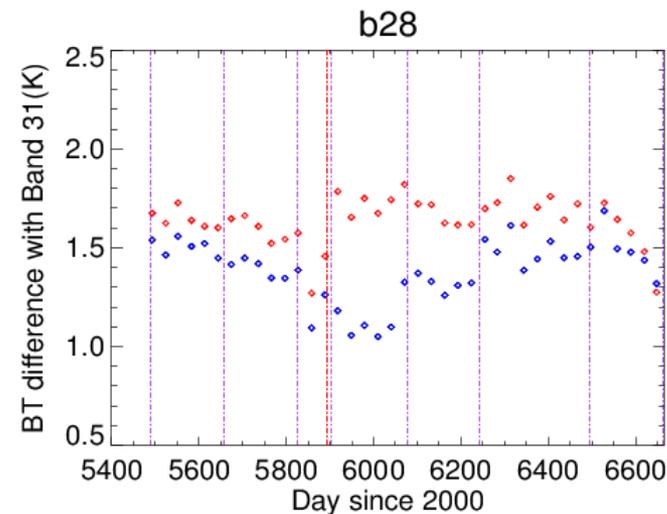
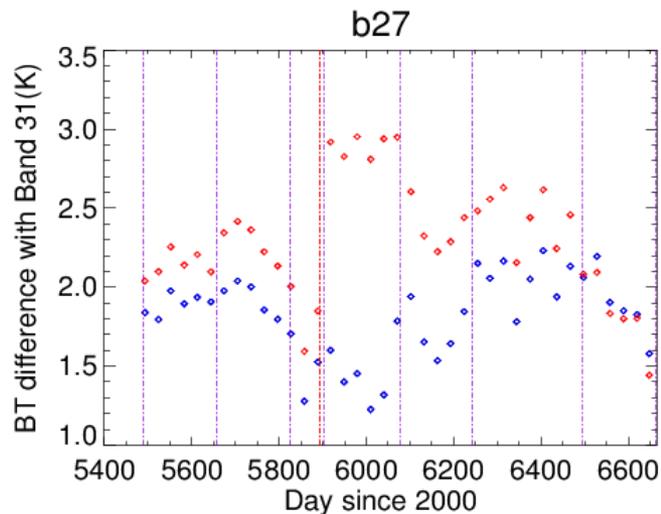
Calibration consistency assessment using DCC



- $a_{0_ms1} = 0$, mirror side two a_0 jumps after safe mode
- The mirror side difference jumps after safe mode for these bands



Calibration consistency assessment using DCC



- Safe mode impacts on the band averaged BT relative to band 31
- The mirror side difference jumps after safe mode for these bands



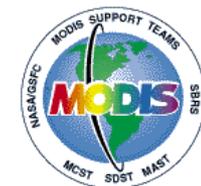
Future calibration improvement and assessment



- Continue to monitor TEB performance using earth view targets and cavity during lunar event, especially for PV LWIR bands.
- Continue to monitor TEB performance using inter-comparison.
- Model observed bias and estimate calibration correction.
- Propose calibration improvement for future collection by combining the calibration algorithm analysis, observation and comparison results, and analytical modeling.
- Propose Terra and Aqua TEB electronic cross-talk corrections in addition to Terra PV LWIR bands (Truman Wilson's talk).
- Seek proper EV targets to assess nonlinear effect in cross-talk correction on L1B product, especially on cold targets.



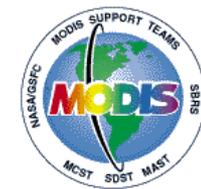
Electronic Crosstalk in the MODIS TEBs



- On August 1, 2018, MCST held a special meeting of the MODIS Sensor Working Group (MsWG) to review the status of electronic crosstalk in MWIR and LWIR bands for both Aqua and Terra MODIS.
 - The full package is available on the MCST FTP site.
 - Today we will just provide a brief review of this workshop.
- Electronic crosstalk has been observed in many MODIS bands since before launch. In particular, the MODIS TEBs 20-25 and 27-30 have been significantly impacted. MCST has been monitoring this issue throughout the mission.
- For bands 27-30 in Terra MODIS, a correction has implemented in Collection 6.1. The same methodology has been extended to the rest of the MWIR and LWIR bands in Aqua and Terra.

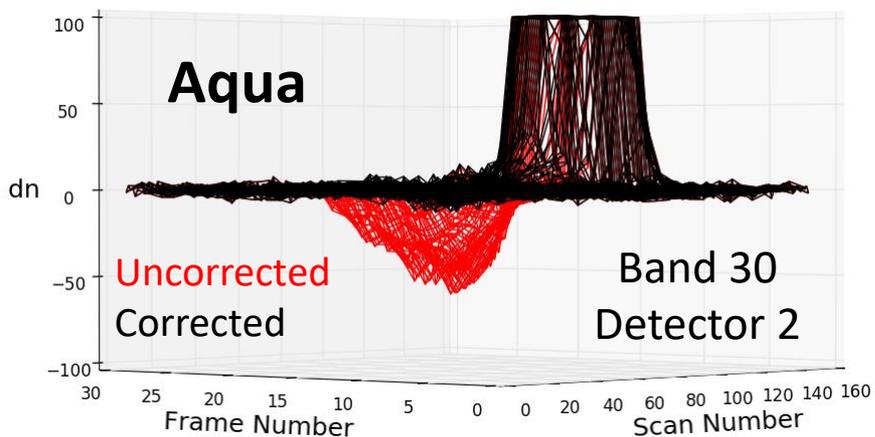
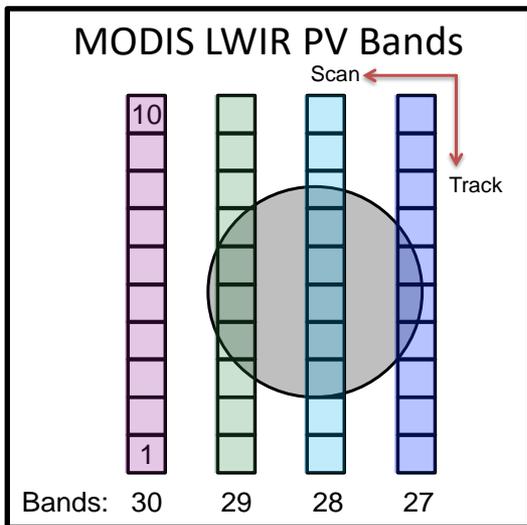
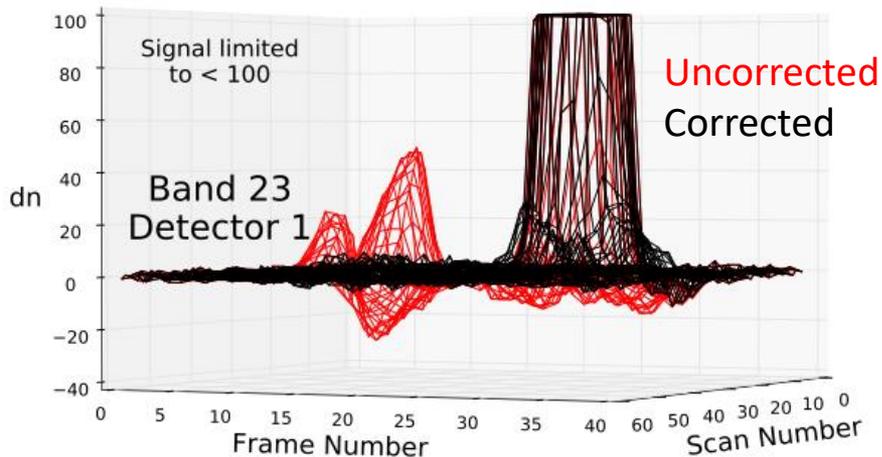
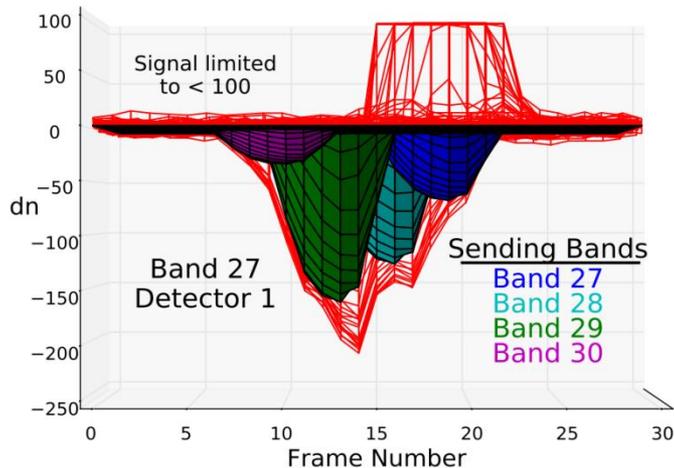


Crosstalk Characterization



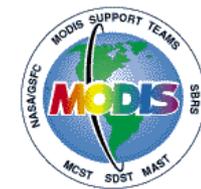
- The Moon has been used extensively for electronic and optical crosstalk characterization and correction for both Aqua and Terra MODIS.

Terra
MODIS

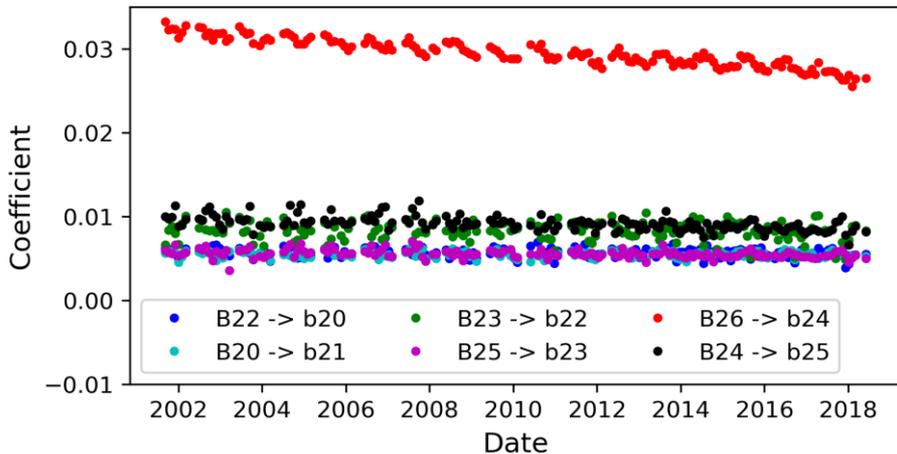




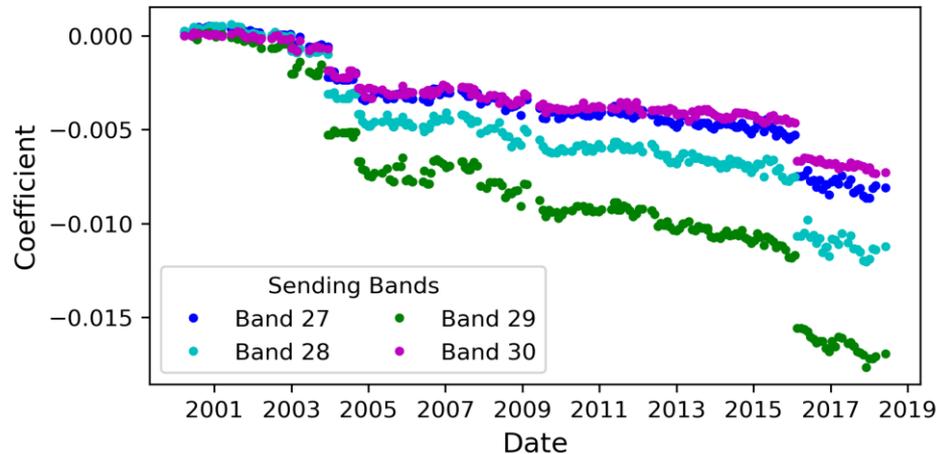
Crosstalk Correction Coefficients



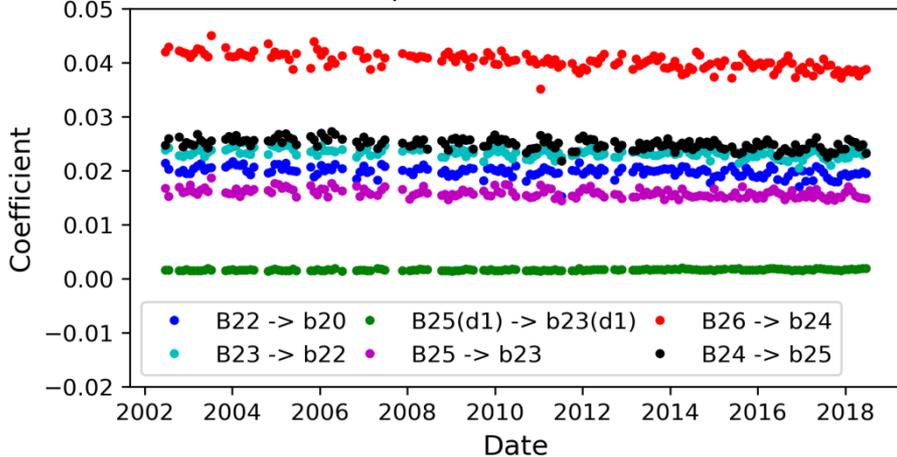
Terra MODIS MWIR D10 to D1



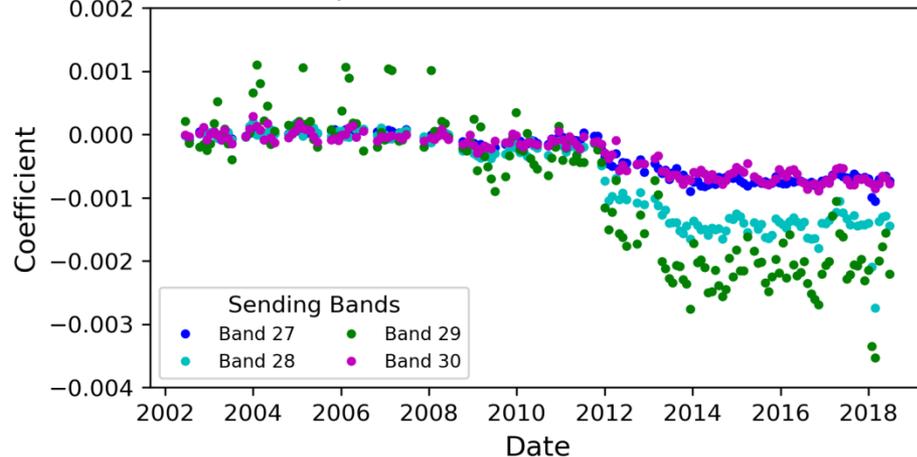
Terra MODIS Band 28, Detector 8



Aqua MODIS MWIR D1

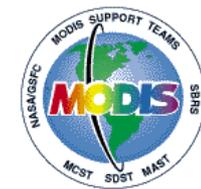


Aqua MODIS Band 29, Detector 6



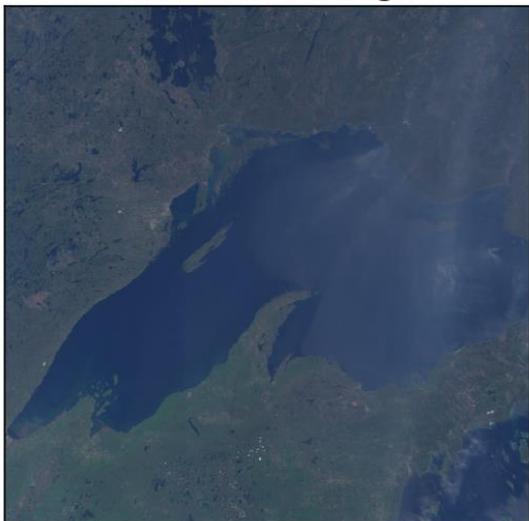


Crosstalk Correction Example



Terra MODIS Band 27

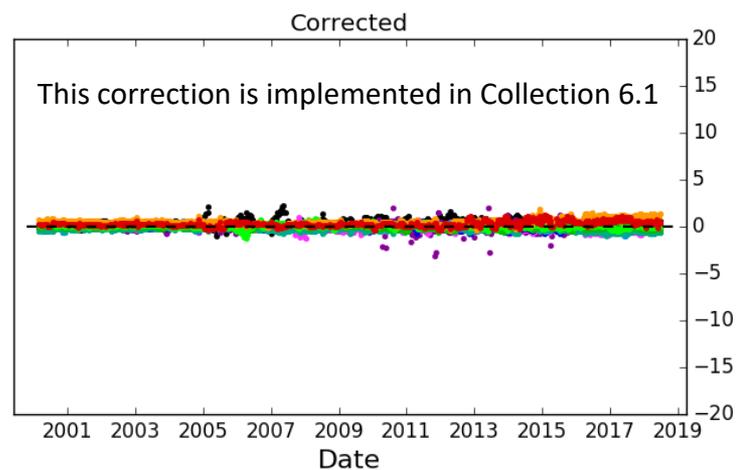
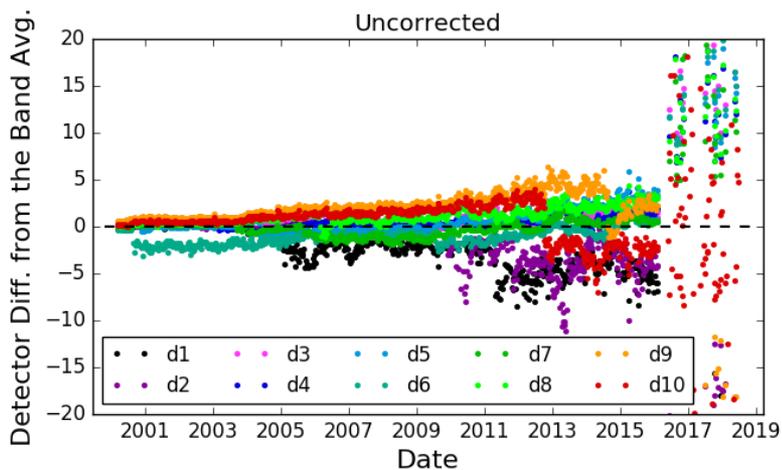
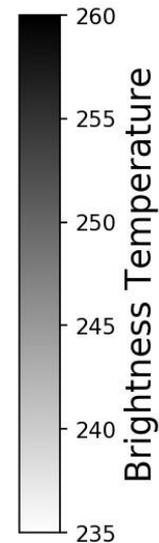
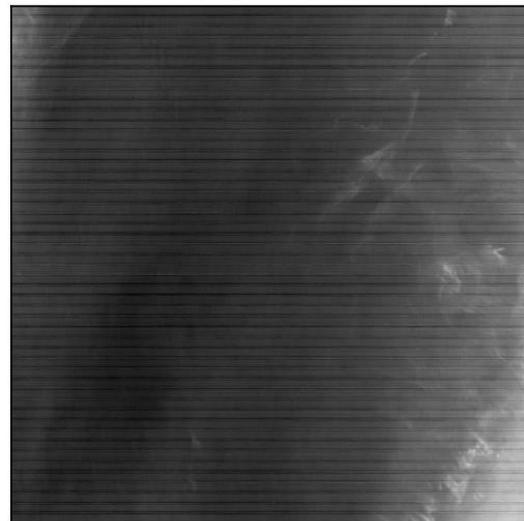
True Color Image



Uncorrected

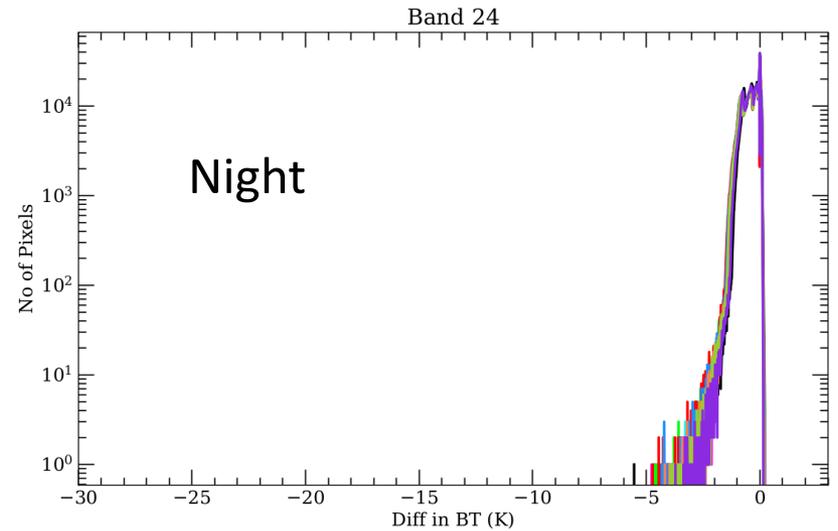
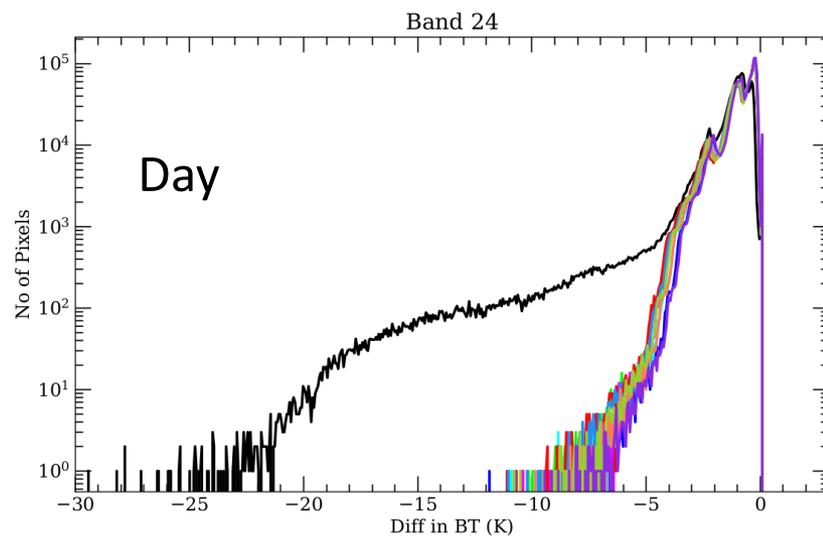
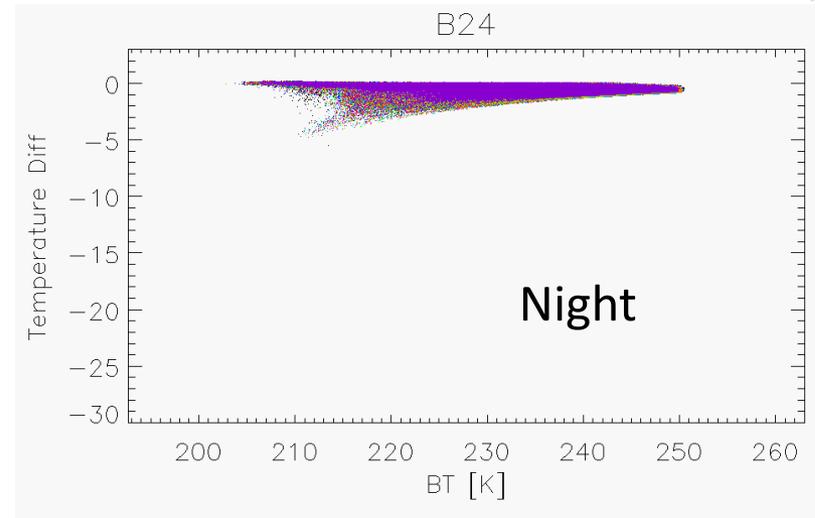
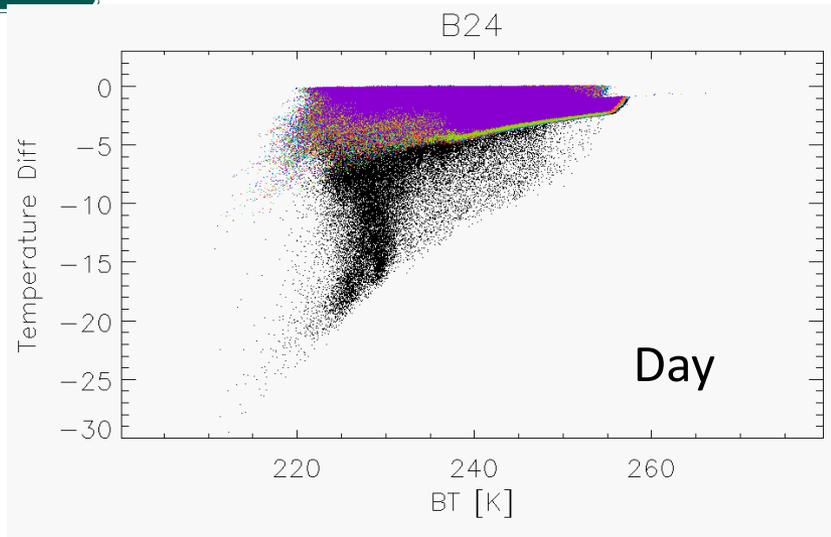
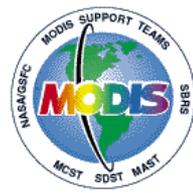


Corrected





Aqua Band 24 Day/Night Difference



d1 d2 d3 d4 d5 d6 d7 d8 d9 d10



Impact Assessment Terra MWIR

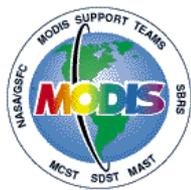


Band	Contamination Impact	Correction Impact	Recommendation
20	No discernable impact.	No Correction Required	No action recommended
21	D1 and D9 striping over water scenes . D1 striping over desert scenes . D9 Striping over ice clouds scenes .	Some image improvement over water. Limited impact over desert and ice clouds.	No action recommended
22	D8 striping over ice cloud scenes (large) and water scenes (~0.5K).	Effectively removes contamination	Apply correction for detector 8
23	D10 striping over ice cloud scenes (large) and water scenes (~0.5K).		Apply correction for detectors 1 and 10
24	D1 striping over ice cloud scenes . 0.5 – 1 K change over ocean scenes for all detectors.	Effectively removes D1 striping. Slight increase in detector spread over ocean scenes.	Apply correction for detector 1
25	No discernable impact	No Correction Required	No action recommended

- The current recommendations are **ready** to be implemented in the Level-1B code



Impact Assessment Terra LWIR



Band	Contamination Impact	Correction Impact	Recommendation
27	Striping and false land/water boundary features. Significant bias that increases throughout the mission, especially after 2016	Effectively removes contamination	A correction is already implemented in Collection 6.1 for all detectors
28	Striping and false land/water boundary features. Significant bias that increases throughout the mission.		
29	Increasing bias and striping throughout the mission. Causes false cloud detection in cloud mask tests.		
30	Increasing bias and striping throughout the mission.		



Impact Assessment Aqua MWIR

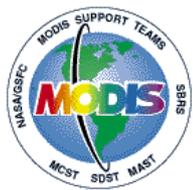


Band	Contamination Impact	Correction Impact	Recommendation
20	D1 impact ~0.15K on average Insignificant impact for others.	Effectively removes contamination	Apply correction for detector 1
21	Contamination is insignificant.	No Correction Required	No action recommended
22	D1 impact ~0.2K on average Insignificant impact for others.	Effectively removes contamination	Apply correction for detector 1
23	D1 striping over ice cloud scenes (large) and water scenes (~0.5K).		
24	D1 striping over low BT scenes during daytime. BT shift at low and high BT scenes	Effectively removes D1 striping over low BT scenes during daytime. Slight increase in detector spread over high BT scenes.	
25	D1 impact ~0.2K on average Insignificant impact for others.	Effectively removes contamination	

- The current recommendations are ready to be implemented in the Level-1B code

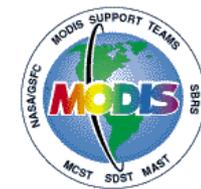


Impact Assessment Aqua LWIR



Band	Contamination Impact	Correction Impact	Recommendation
27	D1 impact ~0.8K on average	Effectively removes contamination	Apply correction for detector 1
28	Contamination is insignificant.	No Correction Required	No action recommended
29	D1 impact ~0.2K D2 (noisy) ~0.25K since 2008 D6 (noisy) ~ 0.35K since 2008	Effectively removes contamination	Apply correction for detectors 1, 2, and 6
30	D1 impact ~0.45K on average Insignificant impact for others.		Apply correction for detector 1

- The current recommendations are ready to be implemented in the Level-1B code



MODIS Spatial and Spectral Performance

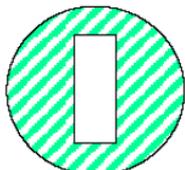




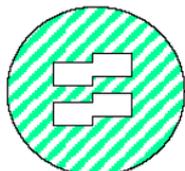
SRCA Layout



Spatial Mode

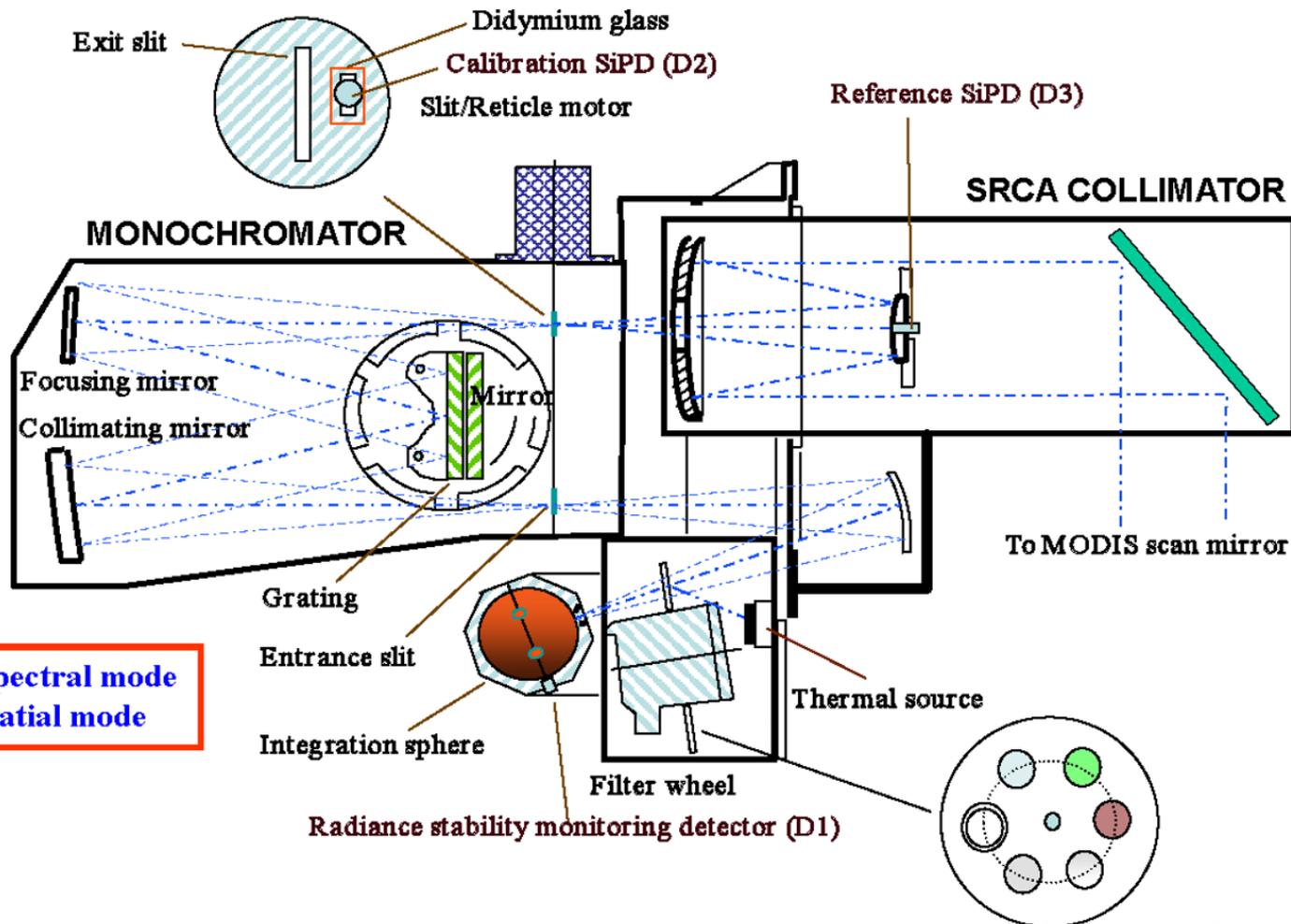
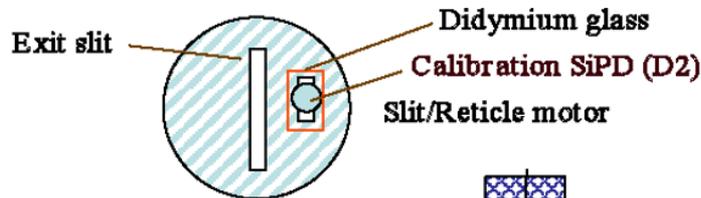


Along-scan



Along-track

Spectral Mode



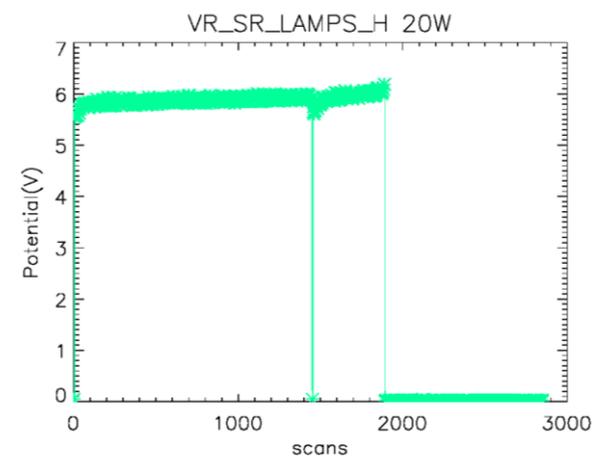
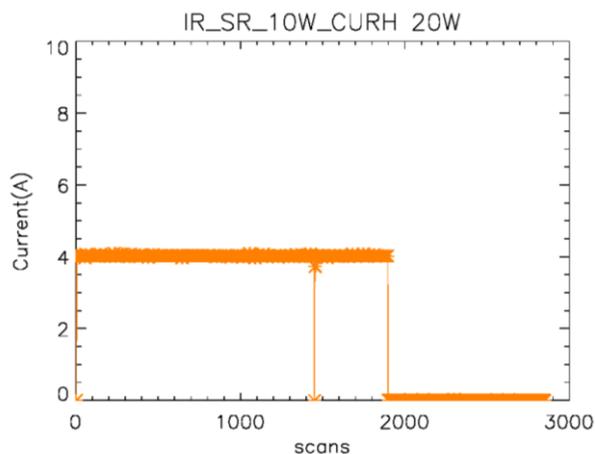
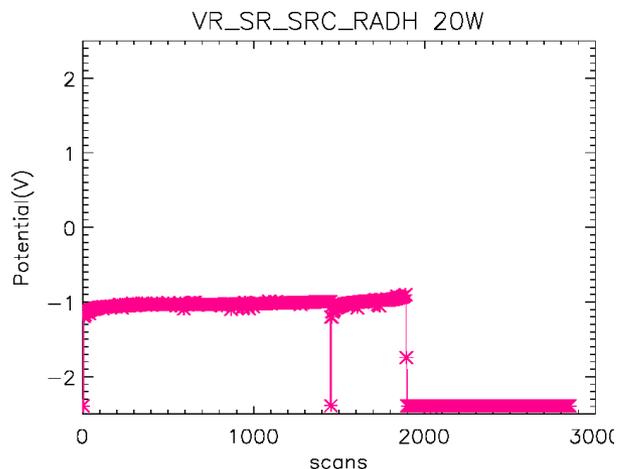
Grating is used for spectral mode
Mirror is used for spatial mode



Aqua Lamp #4 Failure



- During the 20W configuration of the Spectral Calibration on 2016/182, the lamp signal, current, and voltage all unexpectedly went to zero.
- Leading explanation is the overvoltage 'tripped', causing the lamps to turn off



- Subsequent testing performed as expected after executing set-up commands
- As reported at previous science team meeting, Lamp #4 (10W) began exhibiting increased voltage since mid-2015



Impact on Calibration



- Impact on Processing

- Bands that previously used results from 20W source now use 10W source instead
- Spatial bands: **1, 3, 4, 8, 9, 10**
- Spectral bands: **1, 3, 4, 8, 9, 10, 11, 17**
- The 10W source provides enough signal to resolve signal for most bands/calibrations

- Impact on Results

- Aqua band 3 signal is now also too low to resolve spectral data due to switch from 20W to 10W
 - Aqua/Terra band 8 signal became too low to resolve spectral data after switch from 30W to 20W after lamp failures in 2005/2006



Calibration Plan



- IOT commanding procedures were updated to allow calibrations to continue without 20W capability
- To reduce load on SRCA lamps, the calibration frequency was reduced for both instruments after the Aqua lamp #4 failure

SRCA Calibrations per Instrument per Year

	Previous	Revised
Radiometric	12	4
Spatial	4	2
Spectral	3	2



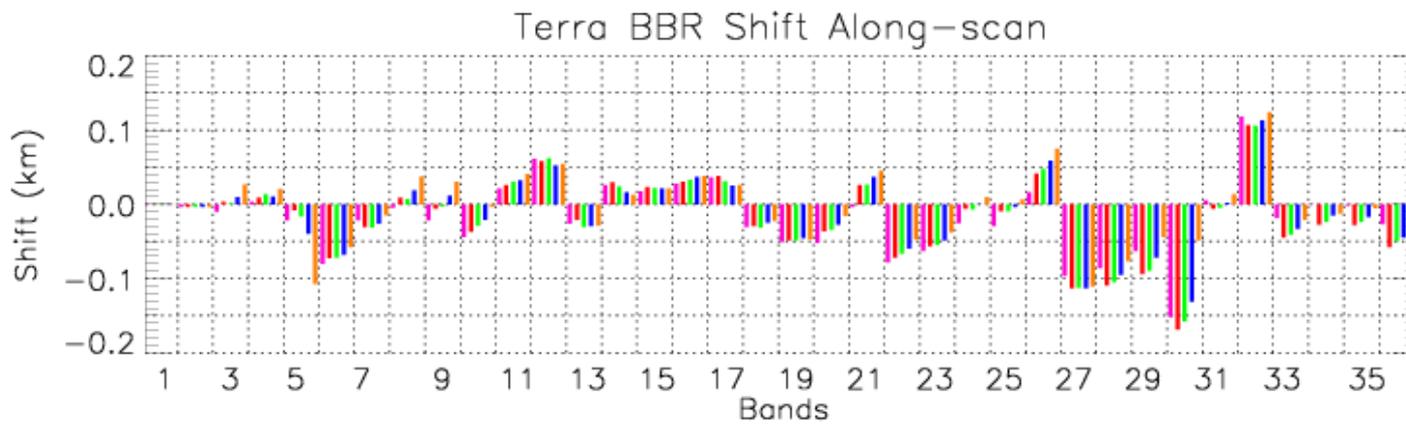
MODIS Spatial Performance



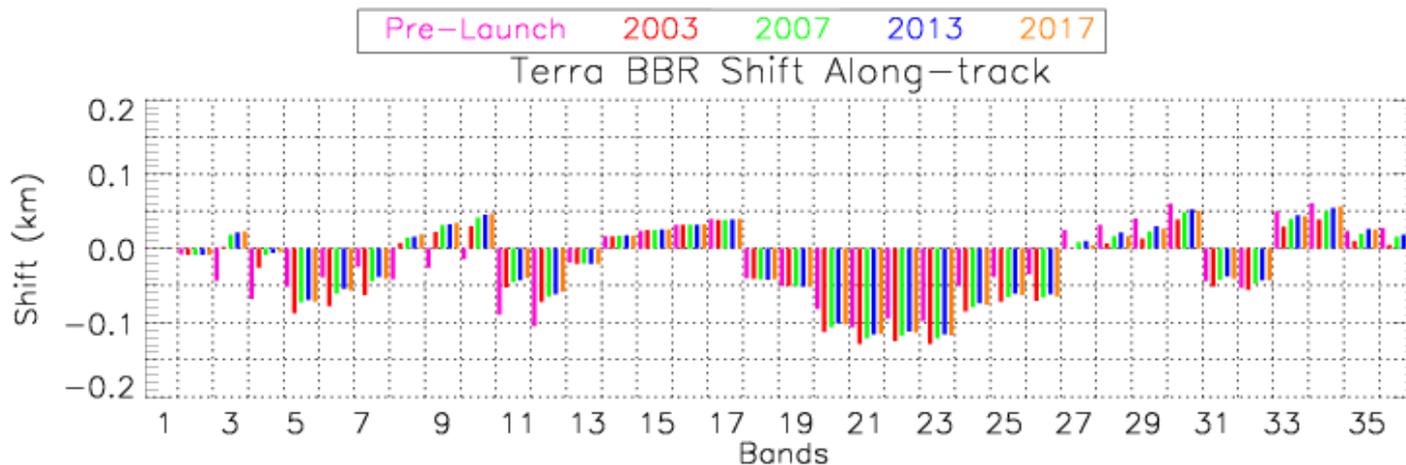
- Spatial calibrations are scheduled every 26 weeks for each instrument
- MODIS BBR design specification is < 200 meters in both directions
- A shift between the cold and warm focal planes in scan and track directions was measured for Aqua MODIS pre-launch
- On-orbit performance for both instruments has remained stable



Band-to-Band Registration



- No bands out of specification

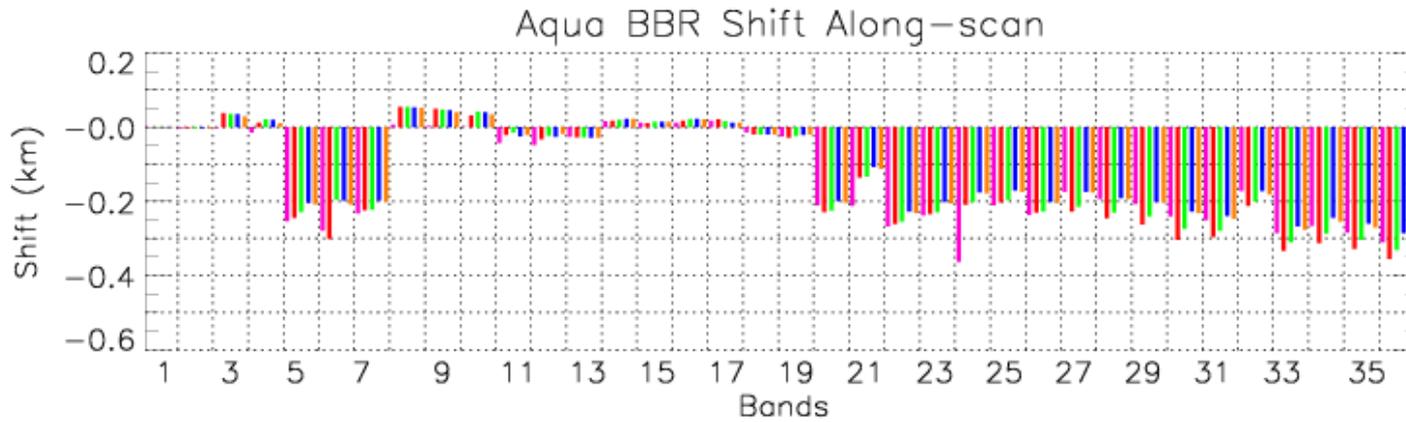


- Only slight drifts observed

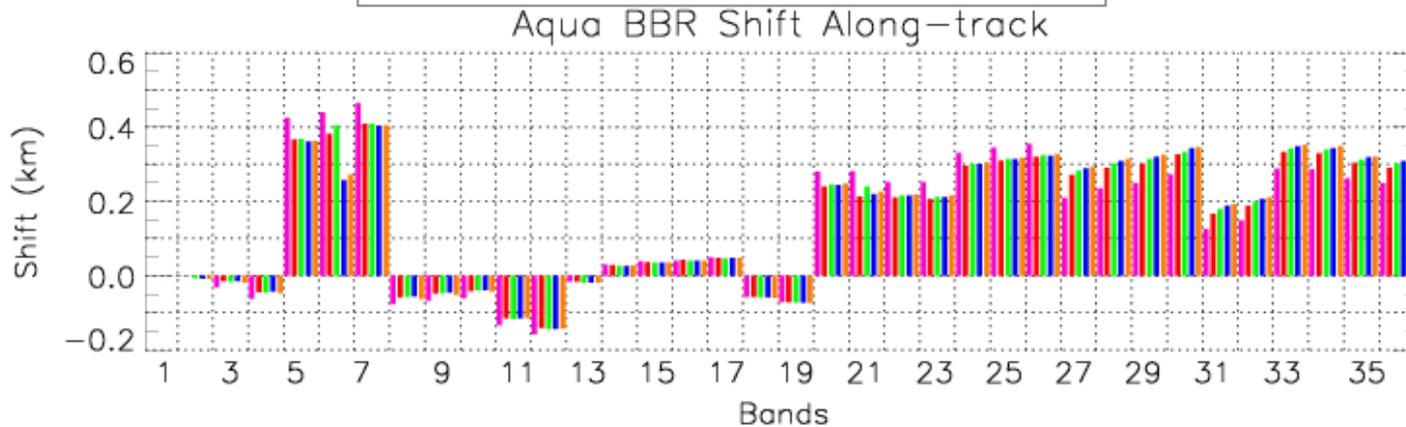
B36 along-track data no longer reported, Detector 7 is classified as inoperable



Band-to-Band Registration



Pre-Launch 2003 2007 2013 2017



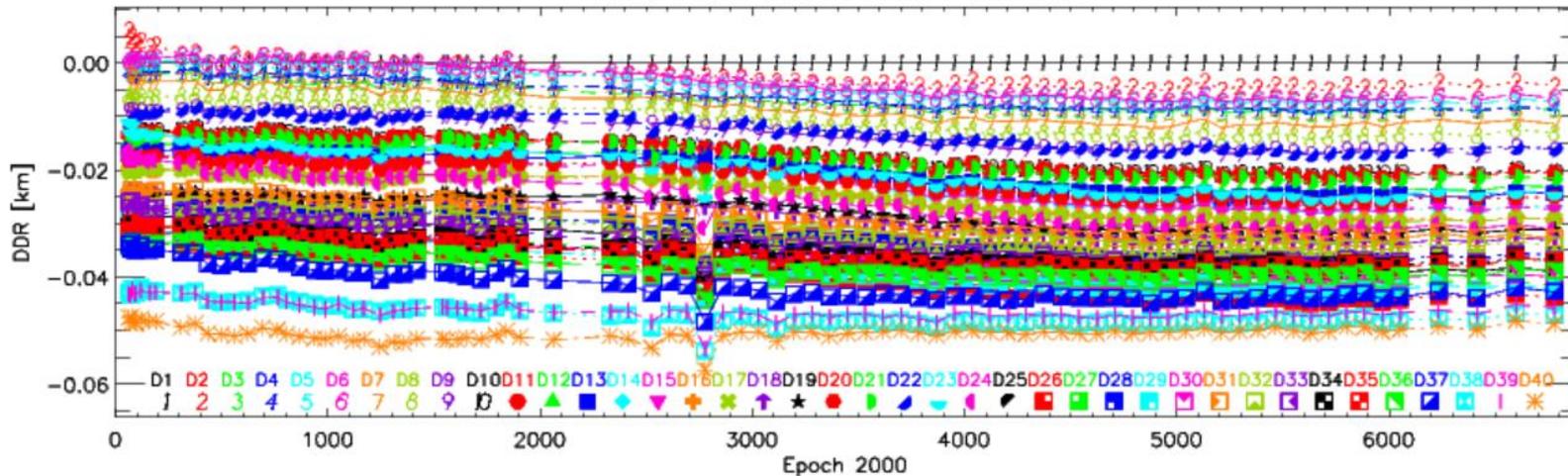
- Cold Focal Plane shift measured prelaunch (200 m)
- Only slight drifts observed



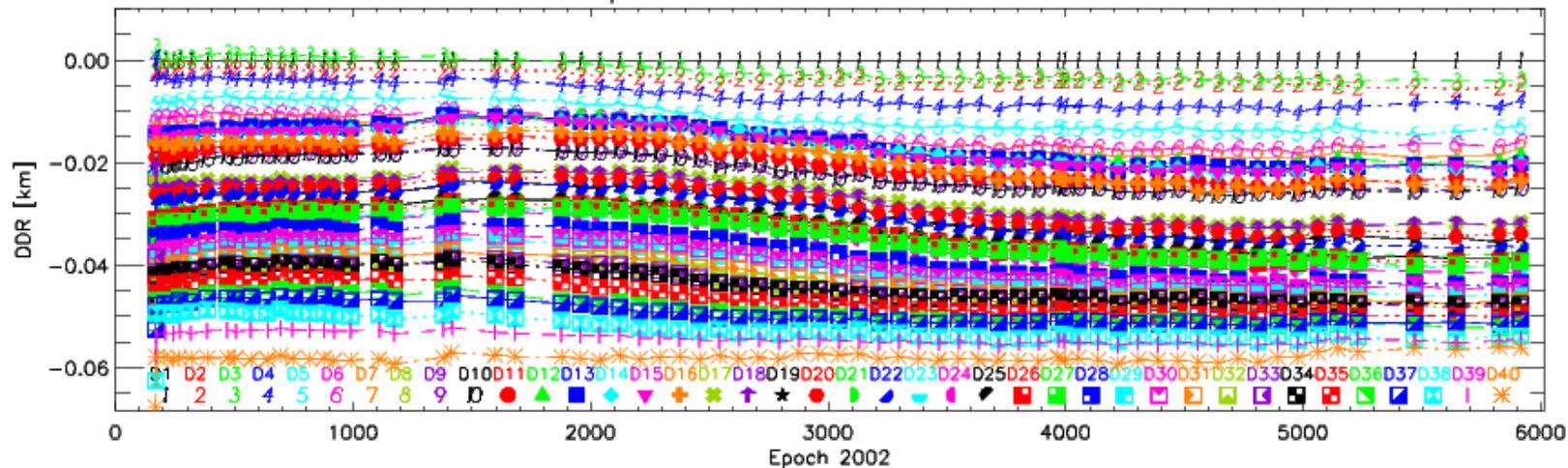
Detector-to-Detector Registration



Terra MODIS DDR in Band 1 and MS 1



Aqua MODIS DDR in Band 1 and MS 1





MODIS Spectral Performance



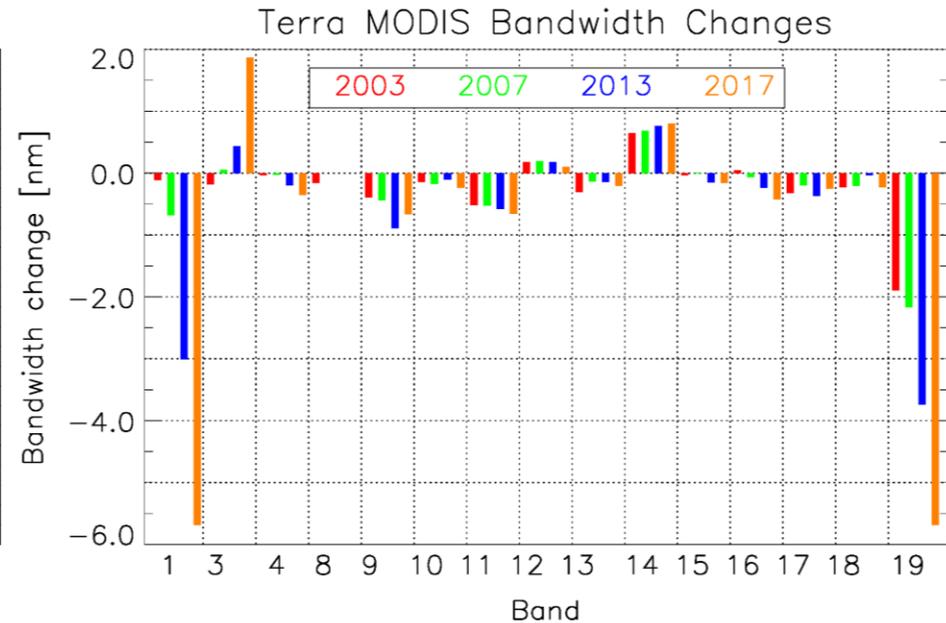
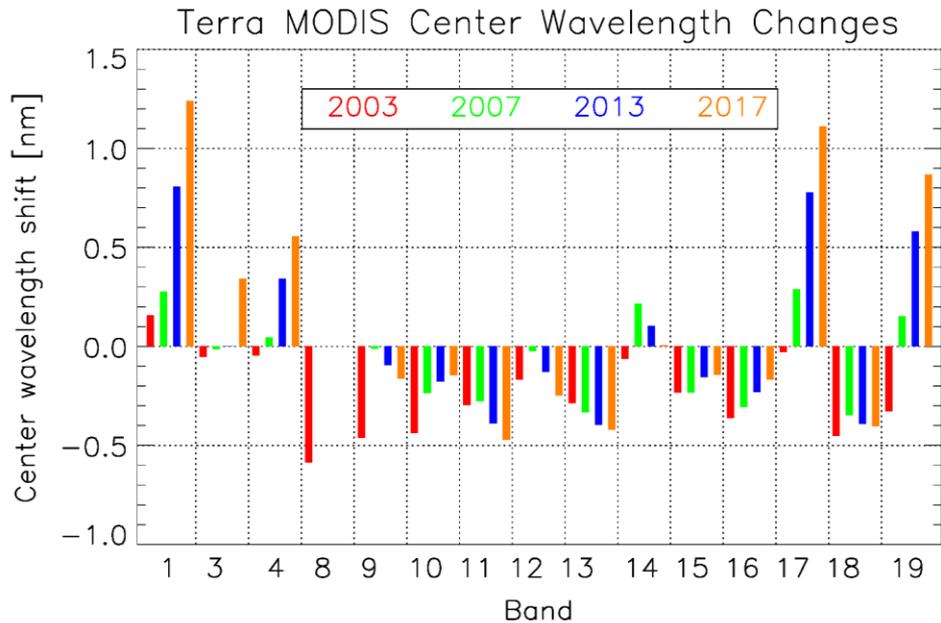
- Spectral calibrations are scheduled every 26 weeks for each instrument
- Measures RSR for most RSB with center wavelengths from 412 nm – 940 nm
- MODIS spectral specifications
 - Stability of center wavelength and bandwidth for VIS bands: 2 nm
 - Other bands: 1% of center wavelength
- All bands continue to operate within specifications



Center Wavelength and Bandwidth



Terra



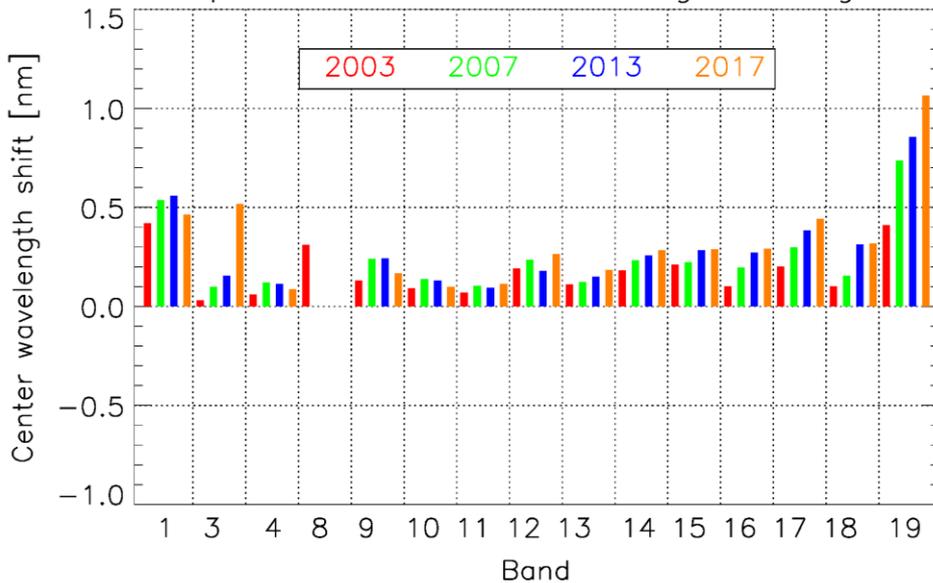


Center Wavelength and Bandwidth

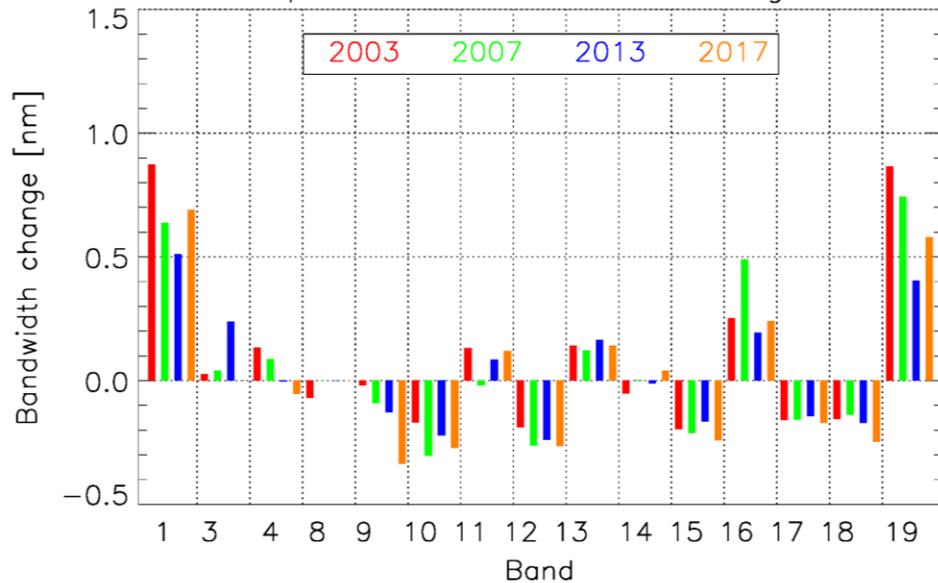


Aqua

Aqua MODIS Center Wavelength Changes



Aqua MODIS Bandwidth Changes





Summary



- Both SRCA instruments continue to operate on a regular basis to provide on-orbit spatial and spectral characterization of MODIS bands
- Coordination between MCST, IOT, and FOT has allowed continued calibrations in light of lamp failures
- On-going Analysis
 - Investigating uncertainty of spectral calibrations has led to areas of potential improvement (background correction)
 - Applying electronic crosstalk correction to PVLWIR band signals in spatial calibration (shift of up to 30 m along-scan)
 - Applying a time-dependent RSR into RSB gain calculation